Upper Colorado River Basin Nonnative and Invasive Aquatic Species Prevention and Control Strategy

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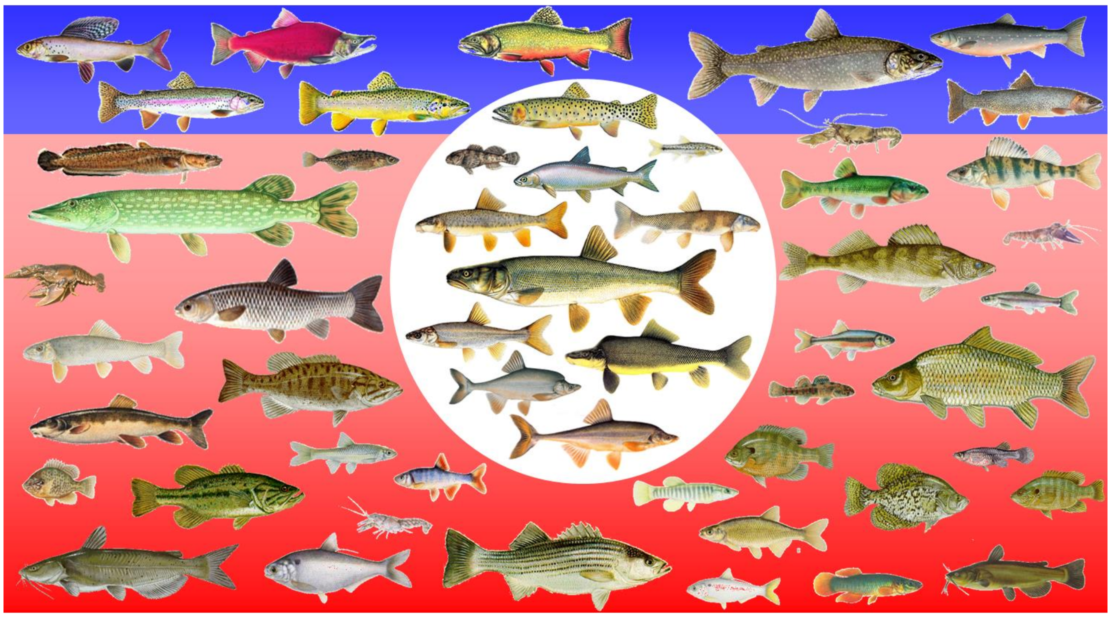

Smallmouth bass predation on endangered bonytail

Northern pike predation on native roundtail chub

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Upper Colorado River Endangered Fish Recovery Program

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Executive Summary

This Upper Colorado River Basin (UCRB) Nonnative and Invasive Aquatic Species Prevention and Control Strategy (Basinwide Strategy) was developed by the Upper Colorado River Endangered Fish Recovery Program (Recovery Program) in response to existing and expanding concerns and populations of nonnative aquatic species within critical habitat of the upper Colorado River basin. Recovery of the four endangered fishes in the UCRB, bonytail *Gila elegans*, humpback chub *G. cypha*, Colorado pikeminnow *Ptychocheilus lucius*, and razorback sucker *Xyrauchen texanus*, requires that the threat of diseases and predation by nonnative species, and the adequacy of existing regulatory mechanisms be addressed and evaluated in the recovery and de-listing process. The Recovery Program is expected to have sufficiently addressed the de-listing criteria per the Endangered Species Act (ESA) such that recovery of these endangered fishes can be achieved and sustained by 2023. This urgency to achieve significant progress toward eliminating or reducing biological threats to the endangered fishes will require that Recovery Program partners expeditiously implement practices, policies, regulations, and enforcement to prevent or minimize the appearance of new threats or the expansion or recurrence of existing threats.

The goal of this Basinwide Strategy is to reduce the negative ecological impact that problematic nonnative aquatic species currently pose or may pose for the native aquatic community in critical habitat so that they no longer are an impediment or threat to the recovery of endangered fishes in the UCRB.

The objectives of this Basinwide Strategy are to:

1) Implement control actions for existing, problematic nonnative predatory fish species (e.g., northern pike *Esox Lucius,* smallmouth bass *Micropterus dolomieu,* and walleye *Sander vitreus*) to expedite their containment, reduction or eradication from source habitats or within critical habitat.

2) Prevent the introduction of additional invasive aquatic species in the UCRB and the expansion in distribution or abundance of the currently existing problematic nonnative aquatic species in the UCRB.

3) Adaptively identify, fund, and implement currently available or new management actions of sufficient scale and intensity to achieve reductions in problematic populations of nonnative aquatic species over the shortest plausible timeframe.

4) Verify the sustained reduction of problematic fish populations in source habitats and within critical habitat to facilitate maintenance of relatively intact native aquatic species community to promote endangered fish recovery.

5) Manage nonnative aquatic species for recreational, research, or commercial purposes that are compatible with endangered fish recovery.

6) Implement policies and practices that ensure enduring control of invasive species and sufficiently remove the threat of problematic nonnative aquatic species in critical habitat and associated waters to help facilitate, achieve, and sustain recovery of endangered fishes.

7) Transfer primary management of nonnative aquatic species from the Recovery Program back to the states of the UCRB by 2023.

This Basinwide Strategy will be implemented by the Recovery Program and its partners via the Recovery Implementation Program Recovery Action Plan (RIPRAP). The RIPRAP was developed, and is modified annually, by Recovery Program partners using the best, most current information available and the recovery goals for the four endangered fish species. It identifies specific actions and time frames currently believed to be required to recover the endangered fishes in the most expeditious manner in the UCRB. The RIPRAP serves as the Recovery Program's short-term and long-term plan, and includes dates for accomplishing specific actions over the next 5 years and beyond. The RIPRAP provides a measure of accomplishment that the U.S. Fish and Wildlife Service uses to determine if the Recovery Program can continue to serve as a reasonable and prudent alternative for water depletion projects undergoing Section 7 consultation to avoid the likelihood of jeopardy to the continued existence of the endangered fishes as well as to avoid the likely destruction or adverse modification of critical habitat.

Specific management actions or strategies (tasks) to be included in the RIPRAP came from:

1) the Nonnative Fish Subcommittee' (NNFSC) summarization, categorization, and prioritization of the collective analyses, discussion and annual modifications to nonnative fish control efforts resulting from the 2002-2009 Nonnative Fish Workshops.; and

2) recent items resulting from presentations and discussions by the Recovery Program's Nonnative Fish Coordinator, including comments received on the draft Basinwide Strategy, at Recovery Program meetings (Biology, Management, and Implementation committees, and the Nonnative Fish Subcommittee), and from the 2010-2012 Nonnative Fish Workshops.

The specific management actions and strategies from these two time periods were combined and incorporated into five major sections in this Basinwide Strategy.

I. Prevention.
II. Eradication, Control, and Management.
III. Research and Monitoring.
IV. Policy and Enforcement.
V. Information and Education.

Recommendations for Sections I-IV of this Basinwide Strategy are contained in Tables ES-1a through ES-8a, below. These tables emulate those in the RIPRAP's Action Plans. The column for "rank" indicates the level of priority, either High, Medium (Med), and Low, initially assigned to each task or strategy. The NNNFSC went through a fairly rigorous prioritization process in August 2008 (see description in NNFSC 2008). For new tasks and strategies (developed since 2008) the assigned priority reflects: 1) input from the Biology and Management Committees; and 2) input from the USFWS during their annual Sufficient Progress reviews of the Recovery Program. For many of these tasks/strategies, the ranking is further described in the Basinwide Strategy. The "who" column identifies the lead responsible agency (listed first) and any cooperating agencies. The status column identifies whether a task or strategy is ongoing, pending, to be performed annually, or is completed. Each task is scheduled to be performed in a specific year or years. The Recovery Action Plans for the General category (Tables ES-1a to ES-1l) are organized according to the four sections: I. Prevention; II. Eradication, Control, and Management; III. Research and Monitoring; and IV. Policy and Enforcement. The remaining Recovery Action plans (Table ES-2a to ES- 8a) contain tasks and strategies for the Colorado and Green River sub-basins and their major tributaries.

The ten-year span of this timeline underscores the urgency to implement these strategies and management actions to secure and sustain recovery by 2023, the anticipated completion date for the Recovery Program when the primary management of the recovered species and their habitat would revert to the states of the UCRB. Given the urgency involved, flexibility will be required for implementation based on availability of funds, personnel, cooperative involvement and agreements, or technology. However, failure to implement these strategies will likely diminish the effectiveness of other recovery strategies (e.g., flow management, habitat restoration, endangered fish stocking) or the likelihood that a community of native aquatic species needed to promote and perpetuate recovery could be sustained. The Basinwide Strategy will continue to follow the experimental approach currently employed by the Recovery Program to combat problematic nonnative species, assess distributions, estimate abundances and reduce threats. Adaptive management principles will continue to be applied. This strategy describes available tactics and actions that help achieve the levels of management necessary to minimize or remove threats to the endangered fishes. Data and information collected will continue to be evaluated annually to determine and refine nonnative fish management actions under the principles of adaptive management. This process has already begun and will not unduly delay timely and effective actions to minimize or remove the nonnative threat to the endangered fishes.

The downlisting of UCRB endangered fishes will require meaningful reductions in the abundance, distribution, and sources of nonnative aquatic species and their negative ecological impact to the native aquatic community to remove the impediment they pose for recovery. It could be argued that the pace of progress has been too slow, particularly as species known to be problematic in one sub-basin begin to invade in another sub-basin. This Basinwide Strategy is intended to accelerate progress to remove the invasive impacts and threat of nonnative fishes in the UCRB to an extent that they are no longer an impediment to recovery over the next decade. The current approach needs to expand to incorporate concepts of invasive species prevention. The probability of success will also be improved through a diversified approach employing more of the available techniques, including treating source populations, incorporating the concept of propagule pressure as a measure of success, and better messaging (e.g., “must kill” regulations, a Stop Illicit Introductions campaign, etc.). Many of the changes in the current approach to nonnative fish management in the UCRB would need to be made through changes to State policies and regulations. This Basinwide Strategy capitalizes on the efforts to address nonnative aquatic species in the UCRB during the past two decades, on the information exchanges in the Recovery Program’s Nonnative Fish Workshops in the past decade, and on scientific information to support its recommendations and provide guidance to implement the changes, policies and practices need to reduce the impacts and threats of nonnative aquatic species in the UCRB.

Agency abbreviations used in Tables ES-1a through ES-8a.

BLM Bureau of Land Management
BR U.S. Bureau of Reclamation
CO State of Colorado
CDA Colorado Department of Agriculture
CDOPR Colorado Division of Parks and Outdoor Recreation (See also CPW)
CDOW Colorado Division of Wildlife (See also CPW)
CRC Catamount Ranch and Club
CPW Colorado Parks and Wildlife (CDOPR & CDOW merged in 2011)
CRRP Upper Colorado River Basin Endangered Fish Recovery Program
CRWCD Colorado River Water Conservation District
CSU Colorado State University
CWCB Colorado Water Conservation Board
FWS U.S. Fish and Wildlife Service
-ES Ecological Services
-FR Fishery Resources
-RW Refuges and Wildlife
-WR Water Resources
LFL Larval Fish Laboratory
NNF Nonnative Fish Sub-committee
NWCD Northern Water Conservancy District
PD/PDO Recovery Program Director
TBD To be determined
UT State of Utah
UDWR Utah Division of Wildlife Resources
UIT Ute Indian Tribe
UTWR Utah Division of Water Resources
UYWCD Upper Yampa River Conservancy District
WAC Water Acquisition Committee
WYGF Wyoming Game and Fish Department

ES-1a. General Recovery Program Support Action Plan. Section I: Prevention.

1a	Activity - GENERAL			FY					
Rank	**PREVENTION**	Who	Status	14	15	16	17	18+	Comments/clarification
High	Maintain and ensure adherence to guidelines and constraints provided in Stocking Procedures for stocking nonnative fishes in public and private waters in the UCRB that are compatible with recovery.	CPW, UDWR, WYGF, FWS	Ongoing	X	X	X	X	X	The Stocking Procedures do not address ongoing or looming invasive impacts arising from species historically or illegally stocked in reservoirs or populations established in rivers that may reach critical habitat.
High	- No stocking of any nonsalmonid species should occur in any stream or river within or connected directly to critical habitat for endangered fishes.	CPW, UDWR, WYGF	Pending	X	X	X	X	X	This issue has recently been clarified and updated in regulations in Colorado and Utah and should be verified in Wyoming.
High	- Obtain Lake Management Plans or other documentation of aquatic species occurrence in UCRB reservoirs/ponds containing nonnative nonsalmonid species which may become invasive in UCRB rivers within critical habitat	PDO, FWS, CPW, UDWR, WYGF	Pending	X	X				An inventory of existing or potentially problematic species in all UCRB reservoirs/ponds is required to assess needs for species reduction, containment or eradication.
High	- Verify direct or indirect connection of effluents from reservoirs or ponds verify if escaping fish would be able to reach critical habitat.	CPW, UDWR, WYGF	Pending	X	X	X			Potential techniques include: semi-buoyant beads, fish telemetry, passive detection sampling gear, etc.
High	- Use sterile hybrid/triploid warmwater sport fishes in UCRB stocking plans	CPW, UDWR, WYGF, FWS	Ongoing	X	X	X	X	X	This technology is not developed for all species, but should be used if available.
Med	- Track annual reporting of nonnative, nonsalmonid, species, sizes, numbers and locations being stocked in UCRB.	FWS	Ongoing	X	X	X	X	X	This reporting is required by the 1996 and 2009 Stocking Procedures for stocking of both public and private waters in the UCRB.
Med	- Verify that management/promotion of sport fishes is consistent with need to provide sport fisheries that are compatible with endangered fish recovery.	CPW, UDWR, WYGF	Pending	X	X	X			Parties to the Stocking Procedures need to review new or revised lake management plans to insure compatibility with endangered species recovery.

ES-1b. General Recovery Program Support Action Plan. Section I: Prevention (continued).

1b	Activity – GENERAL			FY					
Rank	**PREVENTION**	Who	Status	14	15	16	17	18+	Comments/clarification
High	Apply principles and protocols of Prevention (adherence to stocking procedures, Compatible and Non-compatible lists; implement rapid response plans; implement HACCP).	CPW, UDWR, WYGF, FWS	Pending	X	X	X	X	X	The emphasis is on prevention of invasive impacts in critical habitat or in other locations in the UCRB in which the invasive species may reach critical habitat.
High	Adopt and adhere to a List of nonnative aquatic species that are Compatible with promoting, achieving and sustaining endangered fish recovery that can be managed in public and private waters in the UCRB (basin specific).	CPW, UDWR, WYGF, FWS	Pending	X	X	X	X	X	List would conditionally include salmonids, largemouth bass, bluegill, black crappie, yellow perch, wipers, fathead minnow, channel catfish, triploid grass carp and tiger muskie (other sterile triploids or hybrids could be considered in the future). UCRB Compatible Species List would be made public, nationally.
High	- Adopt and announce a List of Non-compatible nonnative aquatic species including those demonstrating severe ecological impacts or threats in the UCRB or LCRB to emphasize their invasiveness and to help prevent their introduction, further spread or stocking in the UCRB (basin specific).	CPW, UDWR, WYGF, FWS	Pending	X	X	X	X	X	Tentative list would include smallmouth bass, northern pike, walleye, crayfish, burbot, flathead catfish, and *Dreissina* spp. UCRB Non-compatible Species List would be made public, nationally.
Med	- Adopt and announce lists of Compatible and Non-compatible aquarium and ornamental fishes and other aquatic species (e.g., plants, (invertebrates, etc.) applicable to UCRB	CPW, UDWR, WYGF, FWS, other State enti-ties	Pending			X	X	X	Some aquarium or ornamental fishes may already appear on the Non-compatible Lists of UCRB states, but these lists likely do not include all potentially invasive taxa and the existing state lists may not include the same species. A Compatible List is a more preventive and simpler approach.
Med	-Recovery Program participation in Aquatic Nuisance Species Task Force	PDO	Pending		X	X	X	X	Participation by PDO in regional ANS meeting may facilitate access to information about progress in controlling existing ANS species, new invasive species or techniques being applied as a rapid-response to avert invasive species spread.

ES-1c. General Recovery Program Support Action Plan. Section I: Prevention (continued).

1c	Activity - GENERAL			FY					
Rank	**PREVENTION**	Who	Status	14	15	16	17	18+	Comments/clarification
High	Implement "Rapid-Response" protocol to respond to appearance of new invasive species or situations in which invasive species that are already present in the UCRB have appeared in a new location or in concentrated numbers.	PDO	Pending		X	X	X	X	In concept, create equivalent of a "fire-truck" or "toxic-spill" response to the appearance of invasive species in accordance with the guidance found in invasive species protocols recommending a rapid-response to prevent or limit invasive spread or invasive impacts by unwanted species.
High	- Identify source of funds and establish funds in reserve that are readily available to deploy rapid-response.	PDO, BR	Pending		X	X	X	X	If funds are from traditional CRRP fund sources, may reduce existing nonnative fish control actions.
High	- Identify personnel who would constitute rapid-response team	TBD	Pending	X	X	X	X	X	State and federal agencies have strict hiring guidelines which may limit their flexibility to assemble rapid-response personnel, particularly outside the traditional spring-autumn field season
Med	- Establish "equipment-cache" to outfit rapid-response team for a variety of habitats (e.g., lotic vs. lentic; high flow vs. low flow) and species (e.g., fish vs. invertebrates)	TBD	Pending		X	X	X	X	Additional considerations include where to store inventory of "rapid-response" equipment cache (multiple locations?).
High	Make HACCP training available to private sector in UCRB to help prevent inadvertent hitchhikers in loads of fish transported to private or public waters.	FWS, State agencies	Ongoing - public Pending - private	X	X			X	HACCP appears to be in use by UCRB state and federal fish hatcheries and managers, but its use in private hatcheries may need to be expanded.

ES-1d. General Recovery Program Support Action Plan. Section II: Eradication, Control, and Management.

1d	Activity - GENERAL			FY					
Rank	**ERADICATION, CONTROL, MANAGEMENT**	Who	Status	14	15	16	17	18+	Comments/clarification
High	Implement “integrated approach” to control nonnative species by applying multiple techniques to expedite reductions in their abundance, invasive impacts, or the threat they pose to native fishes or endangered fish recovery.	CPW, UDWR, WYGF, FWS, PDO	Ongoing	X	X	X	X	X	A variety of strategies and tools are available to bring to bear in the control of problematic species in lotic and lentic habitats. Presently, primary tools are removal of nonnative fishes by electrofishing in rivers or by relying on unlimited bag limits to encourage removal by anglers in rivers and reservoirs. There are a few exceptions where intensive mechanical removal (e.g., NOP in Lake Catamount) or eradication using rotenone (e.g., NOP in Paonia Reservoir) are underway or were performed recently.
High	Fully implement standardized electrofishing concepts, including electrode configurations for boats and rafts, and boat-electrofisher specifications to standardize electrofishing operations per UCRB Recovery Program Electrofishing SOP	CPW, UDWR, FWS, LFL	Ongoing	X	X	X	X	X	Electrofishing course specific to use of UCRB electrofishing boats and rafts using ETS boat-electrofishers scheduled for March 2013.
	- Purchase ETS MBS 1D-72A boat-electrofishers per UCRB Electrofishing SOP specifications	PDO	Ongoing	X					Underway.
	- Apply power-graphs and current-conductivity graphs to select boat-electrofisher settings.	CPW, UDWR, FWS, LFL	Pending	X	X	X	X	X	UCRB-specific electrofishing course is scheduled in 2014 for personnel participating in Recovery Program.
	- Establish fish response thresholds to identify control setting for boat-electrofisher when used in boats and rafts across range of ambient water conductivities encountered		Pending	X					Electrofisher output field forms and notes on fish response.

ES-1e. General Recovery Program Support Action Plan. Section II: Eradication, Control, and Management (cont.).

1e	Activity - GENERAL								
Rank	**ERADICATION, CONTROL, MANAGEMENT**	Who	Status	14	15	16	17	18+	Comments/clarification
High	Identify and rank reservoirs or river reaches for treatment with rotenone or other eradication techniques based on contribution of invasive fishes into critical habitat, feasibility of treatment, and cost.	CPW, UDWR, WYGF, NNFSC	Ongoing	X	X	X			This effort has been initiated by the NNFSC, but the list of water may be incomplete pending inventory of UCRB waters. UDWR recognizes the need to treat Red Fleet Reservoir (SMB & WLY), pending purchase of rotenone via cost share with CRRP.
	- Pursue opportunities that arise to cost-share and expedite elimination of existing or potentially problematic source populations, despite ranking.	CPW, UDWR, WYGF, PDO	Ongoing	X	X	X	X	X	Recent opportunities/needs to cost share the purchase of rotenone have occurred for Paonia (NOP-2012) and Miramonte (SMB-2013) reservoirs in CO. CRRP committed to 50% of rotenone costs for these projects.
	- Implement alternate methods to eradicate invasive fishes (e.g., reservoir draining and drying (may require some rotenone treatment)	CPW, UDWR, WYGF, FWS	Pending	X	X	X	X	X	It may be an option to drain some reservoirs (eg. Elkhead Reservoir)
	Develop hatchery techniques and production capacity for sterile hybrid sportfish (sterile NOP, SMB, and walleye) to serve as compatible replacements	CPW, UDWR, WYGF, FWS	Pending	X	X	X	X	X	Upper Basin State Sportfish Coordinators collaborate with other state and federal personnel to work through a process of identifying and ensuring health/AIS regulations are met in order to create a list of preferred vendors for sterile warm/coolwater fish species.
High	Identify and implement alternate strategies to reduce numbers or escapement of invasive fishes at their source where eradication by draining or chemical treatment is infeasible.	CPW, UDWR, WYGF, PDO, BR	Ongoing	X	X	X	X		Some water bodies may be too large or their inflow/outflow patterns may render the option to use piscicides infeasible.
	- Install, evaluate and maintain structures (i.e. screen) to minimize escapement of invasive species	CPW, UDWR, WYGF	Ongoing	X	X	X	X	X	UT has committed to assessing options to contain / control nonnative predators in Starvation Res by Dec 31, 2013
	- Implement intensive mechanical removal of invasive species as needed (a la Catamount Reservoir)	CPW, UDWR, WYGF	Pending	X	X	X	X	X	States may need assistance for this activity in some reservoirs from other Recovery Program participating agency crews.
	- Adopt regulations near dams, outlets, tailraces, or inflows to diminish abundance of problematic fishes to reduce the risk of escapement.	CPW, UDWR, WYGF	Pending	X	X	X	X		In lieu of reservoir-wide, must-kill regulations, spot regulations near the site of escapement may be beneficial.

ES-1f. General Recovery Program Support Action Plan. Section II: Eradication, Control, and Management (continued)**.**

1f	Activity - GENERAL			FY					
Rank	**ERADICATION, CONTROL, MANAGEMENT**	Who	Status	14	15	16	17	18+	Comments/clarification
High	Monitor screens on all public water to ensure that they are functioning to prevent or control escapement of nonnative fishes, particularly problematic piscivores.	CPW, PDO	Ongoing	X	X	X	X	X	Escapement of stocked and resident nonnative fishes from these reservoirs that may reach critical habitat remains a concern and monitoring should be conducted and reported annually.
	- Reserve use of screens for containing species compatible with recovery of endangered fishes.		Pending	X	X	X	X	X	Screens should not be relied upon to contain species incompatible with the recovery of endangered fishes, including NOP and SMB.
	- Maintain Highline Lake spillway barrier net (Colorado River)	CPW	Ongoing	X	X	X	X	X	Smallmouth bass
	- Maintain Elkhead outlet tower screens (Yampa River)	CPW	Ongoing	X	X	X	X	X	Smallmouth bass, northern pike.
	- Maintain Juniata diversion ditch coanda screen (Gunnison River)	CPW	Ongoing	X	X	X	X	X	Smallmouth bass, walleye.
	- Maintain Rifle Creek coanda screen constructed in 2013	CPW	Ongoing	X	X	X	X	X	Smallmouth bass, northern pike, walleye. Evaluate for five years post-construction to ensure function.
	- All newly installed screens in UCRB.		Pending	X	X	X	X	X	Additional screens may be required.
High	- Evaluate effectiveness and utility of exclusion barriers to limit access to nursery habitats by nonnative small-bodied fishes and predators.	UDWR, FWS, PDO	Ongoing	X	X	X			This strategy may be among the few methods to locally manage the negative impacts of nonnative small-bodied fishes in native fish nursery habitats.

ES-1g. General Recovery Program Support Action Plan. Section II: Eradication, Control, and Management (continued)**.**

1g	Activity - GENERAL			FY					
Rank	**ERADICATION, CONTROL, MANAGEMENT**	Who	Status	14	15	16	17	18+	Comments/clarification
High	Convert "downstream buffers" below known source populations of NOP in the Yampa River into projects focused on eradication of this species in the basin.	CPW, PDO	Pending	X	X	X	X	X	The "downstream buffer" concept implies and conveys a management strategy focused on maintaining and containing NOP rather than eradicating them.
High	Implement "must-kill" regulations for problematic populations/sources of invasive fishes to facilitate angler removal of these species and reinforce message of species' undesirable status.	CPW, UDWR, WYGF	Ongoing – UT, WY Pending – CO		X	X			This component includes a considerable major I&E component from states and CRRP. Must-kill should apply in UCRB states for burbot in all waters, and NOP, SMB, and WLY in lotic habitats.
	- Rescind "wanton waste" regulations to allow anglers to dispose of contaminated (i.e. Hg) or unwanted fish carcasses.	CPW, UDWR, WYGF	Ongoing	X	X				Wanton waste has hampered application of must-kill regulations where fishes are Hg contaminated or if anglers prefer to not consume their catch.
	- Address "immediate offender" citation through public and first law enforcement contact education	CPW, UDWR, WYGF	Pending		X				It may be undesirable to make violators, particularly youth, 'immediate offenders' if they catch and release a species under a 'must-kill' regulation due to unfamiliarity with the regulation or inexperience in fish identification. This can be addressed through public education, for example a warning rather than a citation upon first law enforcement contact.
	- Address angler opposition to "must-kill" through education and enforcement to facilitate angler removal of target species.	CPW, UDWR, WYGF	Ongoing – UT, WY Pending – CO	X	X	X	X		Some anglers who practice "catch & release" may express opposition to regulation requiring them to kill a fish. These anglers also may not want to consume fish they are required to harvest.

ES-1h. General Recovery Program Support Action Plan. Section II: Eradication, Control, and Management (continued)**.**

1h	Activity - GENERAL			FY					
Rank	**ERADICATION, CONTROL, MANAGEMENT**	Who	Status	14	15	16	17	18 +	Comments/clarification
High	Discontinue policy and practice of translocation of invasive, Non-compatible List fishes (i.e. smallmouth bass and northern pike), within the UCRB.	PDO, CPW	Complete	X					Translocation within the UCRB likely reinforced a perception that these species provide options for sport fish management that are compatible with endangered fish recovery.
High	Implement cash or other awards as harvest incentive for active, year-round removal of northern pike or smallmouth bass from critical habitat or source populations of invasive fishes such as BBT, NOP, SMB and WLY in other river reaches or reservoirs.	CPW, UDWR, WYGF, CRRP, water users	Pending	X	X	X	X	X	A bounty is in place at Wolford Mountain Reservoir, CO, for illegally introduced NOP. The bounty is administered by CRWCD. Cash or other incentive may be funded by CRRP, but it is likely that other agencies or entities would have to handle the catch confirmation and incentive payouts.
	- Identify funds to support harvest incentive and set amount/type of incentive.		Pending	X	X	X	X	X	
	- Identify candidate waters for application of harvest incentive.		Pending	X	X			X	Yampa (NOP) and White (SMB) rivers have been proposed for this program.
	- Identify candidate agencies or entities to administer harvest incentives.		Pending	X					CPW and other agencies have local offices in some locations.
	- Promote harvest incentive to facilitate effectiveness.		Pending		X	X	X	X	Would require I&E assistance. Messaging may be more important than the number of fish removed.
	- Monitor and evaluate harvest incentive to facilitate effectiveness.		Pending		X	X	X	X	Verify numbers removed and that program is not undermined by illegal fish movement of target species to sustain payouts.

ES-1i. General Recovery Program Support Action Plan. Section III: Research and Monitoring**.**

1i	Activity - GENERAL			FY					
Rank	**RESEARCH & MONITORING**	Who	Status	14	15	16	17	18+	Comments/clarification
High	Reassess Yampa River target removal densities for NOP and SMB using propagule size approach and make criteria applicable to entire UCRB.	PDO, NNF	Pending	X	X				YAR NNF plan identifies 30 adult SMB/mile and 3 NOP/mile as removal targets (Valdez et al. 2008), but these densities are likely too high to maintain suppression of these invasive species (Breton et al. 2012).
High	Revisit population estimates for NOP and SMB as recommended in pending synthesis reports.	PDO, NNF	Ongoing	X	X	X	X	X	Aggressive removal of invasive species in the UCRB should proceed, relying on modeling results to refine, but not delay, implementation of integrated control.
High	- Evaluate need for ongoing marking and live release of invasive fishes in UCRB for mark-recapture studies.	PDO, CSU, NNF	Pending	X	X				Marking and recapturing marked fish allows population estimation, and monitoring the movement and growth of marked fishes. However, release of invasive fishes for marking studies vs. removal of these fish when initially captured has raised the question whether marking is an ongoing necessity.
High	Establish otolith preparation and analysis services to utilize microchemical techniques to identify origins of fishes captured in UCRB.	PDO, CSU, LFL, CPW, UDWR, WYGF	Ongoing	X	X	X	X	X	Otoliths incorporate distinct natural markers accrued in waters inhabited by fishes. These markers can be used to identify waters from which fish escaped, emigrated, or were illegally moved.
Med	- Additional research may be required to distinguish isotopic markers between reservoirs with similar signatures.		Pending	X	X	X			E.g., Lake Powell and Starvation Reservoir isotopic signatures appear similar.
	- Additional research may be required to improve ability to distinguish isotopic markers between rivers or reaches.		Pending	X	X	X			E.g., Yampa River near Green River confluence and Green River upstream of Yampa River confluence.

ES-1j. General Recovery Program Support Action Plan. Section III: Research and Monitoring (continued).

1j	Activity - GENERAL								
Rank	**RESEARCH & MONITORING**	Who	Status	14	15	16	17	18+	Comments/clarification
High	Investigate influence of discharge on water temperature and habitat inundation or connection in relation to reproduction, recruitment, growth, dispersal, or abundance of nonnative fishes.	LFL, PDO	Pending	X	X				Understanding whether particular nonnative fish species benefit from low or high flows may facilitate improved allocation of removal effort in key habitats.
High	- Evaluate reservoir releases for their effectiveness in promoting reduction and control of nonnative fishes.	LFL, PDO	Ongoing	X	X	X	X		Strategically manipulating flows from Flaming Gorge or Elkhead may reduce water temperature, increase turbidity, or prolong mechanical removal to disrupt reproduction or recruitment of SMB.
Med	- Examine utility of flow releases from Elkhead reservoir for extending period for nonnative fish removal.	PDO, LFL	Ongoing	X	X	X	X	X	Strategic flow releases from Elkhead Reservoir may prolong access to key habitats for extended summertime removal of nonnative fishes, but may diminish storage available to supplement base flows.
High	- Analyze daily growth rings of YOY SMB otoliths to understand spawning chronology in relation to flow events or manipulations.	LFL	Ongoing	X	X				Identifying peak spawning interval may allow focus flow releases or intensified application of mechanical control to interrupt nesting and reduce recruitment.
Med	- Analyze daily growth rings of other nonnative predatory fishes to understand spawning chronology.	TBD	Pending		X	X			Otolith analyses of other species may prove similarly useful in identifying peak spawning interval to facilitate application of treatments to interrupt reproduction and reduce recruitment.
High	Investigate climate change/drought as aggravating factor for invasive species.	PDO, FWS	Pending		X				Anticipate potential in-river thermal benefits or impediments for invasive fishes, crayfishes, diseases or parasites in UCRB.
High	Investigate potential effects of repeated electrofishing on native and endangered fishes.	PDO, CSU	Ongoing	X	X	X	X		Short- and long-term effects of multiple pass electrofishing and repeated exposure of fish to electrical field unknown.

ES-1k. General Recovery Program Support Action Plan. Section III: Research and Monitoring (continued)**.**

1k	Activity - GENERAL			FY					
Rank	**RESEARCH & MONITORING**	Who	Status	14	15	16	17	18 +	Comments/clarification
High	Remove white suckers at fish ladders on Colorado and Gunnison rivers and during electrofishing in Green and Yampa rivers.	FWS, UDWR, LFL, CPW	Ongoing	X	X	X	X	X	White suckers pose a hybridization threat to native suckers and possibly to endangered razorback sucker.
High	- Standardize criteria and photos used to identify hybrids of native and nonnative suckers in the UCRB.	PDO	Complete						Materials used for field identification of sucker hybrids were standardized to the extent possible in 2013.
Low	- Verify visual identification of sucker hybrids vs. genetics.	TBD	Pending					X	Research would compare visual and genetic identification of sucker hybridization.
Med	- Determine size- and age-at-maturity for white sucker by examination of gonads and fin ray sections.	UDWR	Ongoing	X	X	X			Determination of white sucker maturity in relation to age and size may facilitate white sucker removal based on size of fish.
Low	Investigate ecological consequences of partitioning lotic energetic resources between Colorado pikeminnow and nonnative predatory fishes.	PDO, FWS, TBD	Ongoing	X	X				Partitioning available energetic resources among multiple predator species would be expected to reduce carrying capacity for adult Colorado pikeminnow in the UCRB.
Low	Monitor emerging techniques for control or eradication of invasive species in UCRB.	PDO	Pending	X		X		X	Emerging techniques presently in varying stages of development and utility.
Med	- Genetic biocontrol.	TBD	Pending					X	Monitor progress on “breed-to-extinction”.
Low	- Evaluate reproductive fitness and competitiveness of triploid males for mass stocking.	TBD	Pending					X	Technique relies on stocking of sterile males to promote population reduction through reproductive interference.
Med	- Promote research on autocidal, “breed to extinction” techniques	TBD	Pending					X	These techniques may become applicable to cyprinids based on efforts to apply them to common carp eradication (e.g. daughterless carp)
Low	- Visit facility specializing in genetic research on species interest in UCRB (e.g., channel catfish).	TBD	Pending					X	Auburn University would be an example of a facility conducting research that may promote genetic biocontrol.

ES-1l. General Recovery Program Support Action Plan. Section III: Research and Monitoring (continued)**.**

1l	Activity - GENERAL			FY					
Rank	**RESEARCH & MONITORING**	Who	Status	14	15	16	17	18+	Comments/clarification
Low	Monitor emerging techniques for control or eradication of invasive species in UCRB. (**continued**)	PDO	Pending	X		X		X	Emerging techniques presently in varying stages of development and utility.
Low	- Use non-physical, stimulus barrier screens to control escapement or movements of nonnative fishes.	TBD	Pending	X		X		X	These might include/combine electrical, strobe, acoustic, or bubble stimuli to guide, deflect or deter fish movements. Electric screen at Tusher Wash may provide data supporting use of this technology for control of movements by nonnative fishes.
Med	- Investigate availability/utility of physical techniques to control nonnative fishes.	TBD	Pending	X		X		X	Pulse pressure techniques may provide option for disrupting spawning by nonnative fishes in shallow water (e.g., northern pike) by causing mortality of spawning adults or by causing mortality of deposited eggs.
Med	- Determine if additional chemicals (pesticides) are available/suitable for eradicating or controlling problematic species.	TBD	Pending	X	X				Ammonia is an example of a chemical that has been used at small-scales to eradicate invasive fishes and crayfish.
Low	- Apply invertebrate control techniques to prevent or reduce negative ecological impacts to native aquatic community.	TBD	Pending					X	Crayfish, for example, alternative aquatic food webs through competition, predation and by supporting hyperpredation by invasive fishes (e.g., SMB).
High	- Prohibit live movement of all crayfish species in UCRB.	CPW, UDWR, WYGF	Ongoing	X	X	X	X	X	Prohibition in place for all crayfish in CO and UT, but only for rusty crayfish in WY.
Low	- Biocontrol.	TBD	Pending					X	E.g., use of diseases, parasites, predators or competitors to control invasive species.
Low	- Use pheromones as attractants to promote trapping of invasive fishes	TBD	Pending					X	This technique may improve removal efforts for some nonnative species.
Low	- Environmental DNA (eDNA).	TBD	Pending					X	eDNA may facilitate early detection of invading or newly introduced species.

ES-1m. General Recovery Program Support Action Plan. Section IV: Policy and Enforcement**.**

1m	Activity - GENERAL								
Rank	**POLICY & ENFORCEMENT**	Who	Status	14	15	16	17	18+	Comments/clarification
Med	Transition maintenance activities to maintain suppression of invasive aquatic species within critical habitat from Recovery Program back to UCRB states	PDO, CPW, UDWR, WYGF	Pending					X	Planning should occur five years in advance of transition back to primary control of nonnative aquatic species by UCRB states.
High	Promote UBRB-wide cross-jurisdictional coordination for invasive species and sport fish management in UCRB to emphasize ecological rather than political boundaries.	PDO, CSU	Pending	X	X	X	X	X	Coordinated management emphasizing ecological realities rather than political boundaries or policies is needed to combat invasive impacts of Non-compatible list species, including predaceous sport fish.
High	- Provide I&E about predatory impacts of nonnative piscivores on native fishes	CRRP		X	X	X	X	X	Large-bodied nonnative piscivores reduce carrying capacity for Colorado pikeminnow
High	Implement consistent policies, regulations, and penalties for illegal stocking among the states in the UCRB.	CPW, UDWR, WYGF	Pending	X	X				The problem of illegal stocking is now basin-wide and getting worse – a more coordinated UCRB effort is required.
	- Make fines and penalties for illegal introduction of nonnative aquatic species the same in UCRB states including CO, UT, and WY.	CPW, UDWR, WYGF	Pending	X	X				$10,000 (WY), which is the presently the severest monetary penalty for this illegal activity in the UCRB and other states should adopt similar penalties.
	- Make loss of fishing/hunting privileges and equipment the same among UCRB states for illegal stocking	CPW, UDWR, WYGF	Pending	X	X				Same or more similar penalties should exist among UCRB states.
	- Make rewards for witness incentives the same among UCRB states.	CPW, UDWR, WYGF	Pending		X				The message regarding the criminal nature of illegal stocking among UCRB states should be the same/similar.
	-Work with the court system to develop a better understanding of the ecological / financial damage caused by illegal introductions	CPW, UDWR, WYGF	Pending	X	X				Utah recently convicted an individual of illegal introduction – he was found guilty, but fined for just over $300.

ES-1n. General Recovery Program Support Action Plan. Section IV: Policy and Enforcement (continued)**.**

1n	Activity - GENERAL			FY					
Rank	**POLICY & ENFORCEMENT**	Who	Status	14	15	16	17	18+	Comments/clarification
High	Consistently define, intensify surveillance, provide informant incentives, and greatly increase penalties for unauthorized transport of fish to intercept or avert illegal stocking before actual illegal release of nonnative aquatic species occurs.	CPW, UDWR, WYGF	Pending	X	X	X	X		Detection and prosecution of illegal stocking after the fact can be difficult if the act is unwitnessed, or repetitive. Intervention at the earlier, more preventable stage when fish are being transported, prior to the act and violation of actually performing the act of illegally releasing, stocking or introducing species should become a more serious offense in the UCRB with correspondingly more severe penalties and deterrents.
High	- Make penalties for illegal transport in UCRB more severe with increased fines, equipment seizure, loss of fish /hunt privileges, and witness incentives.	CPW, UDWR, WYGF	Pending	X	X				Penalties for unauthorized transport of fish must become more severe in CO, UT and WY, and should include increased education and enforcement.
High	Designate Native Fish Conservation Areas (NFCA) in the UCRB to promote need for relatively intact native aquatic community to achieve endangered fish recovery and to prevent future listings of additional "big river" fishes.	CPW, UDWR, WYGF, BLM	Pending	X	X	X	X	X	Mainstem rivers and their floodplains in the UCRB are essential habitats, particularly within critical habitat, for the maintenance of a native, warmwater, riverine aquatic community. This concept is poorly recognized among agencies, anglers, or the public. Designating NFCAs would provide a basis for education and protection of these aquatic habitats and communities.

ES-1o. General Recovery Program Support Action Plan. Section V: Information and Education**.**

1o	Activity - GENERAL			FY					
Rank	**INFORMATION AND EDUCATION**	Who	Status	14	15	16	17	18+	Comments/clarification
High	I&E Committee will need to assist the State agencies by developing / implementing specific public outreach plans (written communication, public meetings, social media, etc.) related to new management (e.g. rotenone application, cease translocation, etc.) or policy (e.g. must kill regs., harvest incentives, etc.) actions.	I&E Comm, CPW, UDWR, WYGF	Pending	X	X	X	X	X	The program will need to employ the expertise of the I&E Comm to assist with important, but controversial messages particularly when the message contradicts previous Program positions (e.g. those presented in the Yampa Management Plan). The I&E Comm may choose to conduct a Human Dimensions Study to identify a messaging approach that has the greatest probability of long term success.
High	Develop a one-page flyer / press releases that highlights the benefits of the Recovery Program and predatory impacts of nonnative predators to be distributed by staff members.	Same as above	Pending	X	X				Flyers should be posted on community bulletin boards or in other places frequented by the public.
Med	Develop / maintain a web page specific to the nonnative predator threat to recovery.	Same as above	Pending		X	X	X	X	Messages could include – current NNF management, prevention of nonnative introductions, critical habitat designations, proper fish locations, future native fishery opportunities, implications of climate change
Med	Develop a list of potential communication partners outside of the Program.	Same as above	Pending	X	X	X	X	X	Potential partners should be contacted to team on non-native fish control communication efforts.
High	Continue to educate children and anglers about native fishes and negative impacts of nonnative predators	Same as above	Pending	X	X	X	X	X	Success in the long term will depend on changing general attitude to native fish conservation.

ES-2a. Green River Mainstem Action Plan.

2a	Activity – GREEN MAINSTEM	Who	Status	FY					Comments/clarification
Rank				14	15	16	17	18+	
High	Reduce threat posed by walleye (WLY) and smallmouth bass (SMB) populations, including their escapement from reservoirs in Green River basin in Utah or Wyoming.	UDWR, WYGF	Ongoing	X	X	X	X	X	SMB and WLY have been historically or illegally established in major reservoirs in the Green River basin. There is concern that these sources may contribute to the abundance of these species in critical habitat. WLY and SMB escape from Starvation and may also escape from Red Fleet, where they were illegally established.
High	- Apply rotenone in Red Fleet Reservoir to eradicate its illegally established SMB and WLY populations and reestablish sport fishery compatible with recovery.	UDWR, PDO	Ongoing	X	X				UDWR has proposed rotenone treatment of Red Fleet Reservoir for 2014. CRRP will cost share the purchase of rotenone. A sport fishery compatible with endangered fish recovery will be reestablished
Med	- Adopt must-kill regulation for nonsalmonid predatory sport fishes (i.e. SMB and WLY) near dam at Starvation Reservoir to reduce their density near point(s) of water release (i.e. outlets, spillway) to reduce the risk of escapement or entrainment.	UDWR	Pending					X	In lieu of reservoir-wide, must-kill regulations, spot regulations near the site of escapement/entrainment may be beneficial to help reduce number of fish moving up into riverine critical habitat.
Low	- Adopt must-kill regulation for SMB near dam at Flaming Gorge Reservoir to reduce their density near point(s) of water release (i.e. outlets, spillway) to reduce escapement/entrainment risk.	UDWR	Pending					X	In lieu of reservoir-wide, must-kill regulations, spot regulations near the site of escapement/entrainment may be beneficial to help reduce number of fish moving up into riverine critical habitat.
Med	- Further investigate source of WLY in lower, middle, and upper reaches of Green River to determine if origin is primarily from one or multiple source populations, or if in-river recruitment has become a major contributor.	UDWR, PDO	Pending	X	X	X			Collect and analyze otoliths to determine WLY origins by river reach to better focus WLY control at sources or on WLY produced in the Green River.

ES-2b. Green River Mainstem Action Plan (continued).

2b	Activity – GREEN MAINSTEM	Who	Status	FY					Comments/clarification
Rank				14	15	16	17	18+	
High	Implement integrated approach to eradicate/remove NOP in Green River, including its mainstem, floodplain nursery habitats or reservoir source populations.	UDWR, CPW, FWS, LFL	Ongoing	X	X	X	X	X	Recent increase in northern pike in UT may facilitate further establishment by this species in Green River mainstem, floodplain or wetland habitats.
	- Intensify efforts to remove and eradicate northern pike	UDWR, CPW, LFL	Ongoing	X	X	X	X	X	Northern pike now occur in and above Browns Park in CO and UT.
	- Implement must-kill regulation for northern pike in Green River basin	UDWR, CPW	Ongoing	X	X	X	X	X	UT has implemented a must-kill regulation for NOP in the Green River.
High	Investigate Flaming Gorge releases as means to disadvantage nonnative fishes in Green River.	LFL, BR, PDO	Ongoing	X	X	X	X		Need to understand effects of managed flows for native and endangered fishes and multiple species of nonnative fishes.
High	Implement must-kill regulation for burbot in Green River basin within Wyoming, including Flaming Gorge Reservoir. Two BBT have been captured in the Green River as of 2012.	WYGF	Complete	X	X	X	X	X	The purpose of efforts to promote angler harvest of invasive burbot in Flaming Gorge would be clarified by must-kill regulation and would help avoid misinterpretation about angling as the principle means being applied to reduce and control BBT spread and abundance n the UCRB.
High	- Support effort by WYGF to change the status of illegally introduced game fish populations, in specific waters, to be properly disposed of following harvest without regard to edible portions.	PDO	Complete	X					Draft language for regulation change has been drafted by WYGF and reviewed by CRRP. CRRP supported the proposal as drafted.
High	- Implement must-kill to burbot in UT	UDWR	Complete	X	X	X	X	X	Burbot must be killed if caught anywhere in UT.
High	-Apply must-kill to burbot in CO	CPW	Pending	X	X				Unlimited bag limit applied to burbot in 2013.
High	Assess utility of backwater barriers to exclude nonnative fish and promote recruitment of Colorado pikeminnow.	UDWR, FWS, PDO	Ongoing	X	X				If successful, this technique may be useful in other locations in the UCRB.
Low	-Investigate food web impact of gizzard shad	TBD	Pending					X	Gizzard shad role in food web of UCRB rivers is unknown at present.

ES-3a. Yampa and Little Snake Rivers Action Plan.

3a	Activity – YAMPA & L. SNAKE			FY					
Rank		Who	Status	14	15	16	17	18+	Comments/clarification
High	Implement integrated approach to eradicate/remove NOP in Yampa River basin, including its mainstem, floodplain nursery habitats and reservoir source populations.	PDO, CPW, FWS	Ongoing	X	X	X	X	X	The NOP density within critical habitat exceeds that of Colorado pikeminnow (CPM). Adult CPM density in the Yampa River has been reduced to about 0.5/mile by 2013 and NOP from the Yampa continue to move into other rivers (e.g., Green & Little Snake).
High	- Apply intensive mechanical removal methods in river.	CPW, PDO	Ongoing	X	X	X	X	X	CPW approach to reduce northern pike in Lake Catamount used multiple gear types.
High	- Inventory and modify as necessary, key pike reproductive or nursery habitats to reduce production of northern pike.	CPW, PDO	Ongoing	X	X	X	X		CPW has demonstrated the local effectiveness of such actions at Chuck Lewis State Wildlife Area to reduce available spawning/recruitment habitat for NOP. Also applicable to RM 151 backwater and Walton Ck confluence area.
High	- Implement bounty for NOP in Yampa River basin.	PDO, CPW	Pending		X	X	X	X	This strategy should be adopted and evaluated for a period of at least five years.
High	Eradicate smallmouth bass and northern pike in Elkhead Reservoir to eliminate this source of these species to the Yampa River.	CPW, CRWCD & PDO	Pending	X	X				Both SMB and NOP are known to escape from Elkhead.
High	- Identify and implement options to remove these species from within and upstream of the reservoir.	CPW, PDO	Pending	X	X	X			CPW will work with local interests to implement this action.
High	- Identify and facilitate replacement fishery for reservoir.	CPW	Pending	X	X	X	X		Fishing can be immediately restored by stocking catchable rainbow trout, but water quality criteria may confound this option. Stocking of compatible warmwater fishes may require multiple years of stocking to restore fishable populations.

ES-3b. Yampa and Little Snake Rivers Action Plan (continued).

3b	Activity – YAMPA & L. SNAKE			FY					
Rank		Who	Status	14	15	16	17	18+	Comments/clarification
High	Eradicate northern pike (NOP) and walleye (WLY) in upper Yampa River reservoirs to eliminate these populations as sources of escapement downstream or as sources for illegal introduction of this species.	CPW, PDO		X	X	X	X		NOP and WLY were illegally introduced into Stagecoach Reservoir and NOP subsequently spread downstream into the privately owned Catamount Reservoir where their numbers exploded. NOP have also been illegally spread to other smaller waters in the upper Yampa River basin which support salmonid fisheries.
High	- Eradicate NOP and WLY in Stagecoach Reservoir.	CPW, UYWCD, PDO	Pending	X	X	X	X	X	Present tagging and monitoring performed by CPW could be converted to intensive removal of NOP
High	- Establish must-kill regulation for NOP and WLY in Stagecoach	CPW	Pending	X	X				Efforts to eradicate NOP and WLY populations in Stagecoach Reservoir will be needed to increase the probability of success downstream. A must-kill regulation would clarify the intent of this effort to permanently eradicate NOP in Stagecoach Reservoir.
High	- Eradicate NOP below Stagecoach Reservoir, above and within Catamount Reservoir.	CPW, CRC, PDO	Pending		X	X			CPW currently performs intensive mechanical removal of NOP in privately owned Catamount Reservoir. CRC has implemented a must-kill regulation for NOP in the reservoir. Other control techniques may be needed in the future.

ES-3c. Yampa and Little Snake Rivers Action Plan (continued)

3c	Activity – YAMPA & L. SNAKE			FY					
Rank		Who	Status	14	15	16	17	18+	Comments/clarification
High	Implement integrated approach to reduce smallmouth bass abundance in Yampa River critical habitat.	LFL, CPW, FWS	Ongoing	X	X	X	X	X	Smallmouth bass continue to dominate as nonnative predator within Yampa River critical habitat for Colorado pikeminnow.
	- Focus on habitats where SMB reproduction is concentrated.		Ongoing	X	X	X	X	X	Knowledge about key reaches highly suited to SMB reproduction has increased in recent years.
	- Focus on disrupting SMB nesting after flows drop and waters temperature rises.		Ongoing	X	X	X	X	X	"Surge" approach to increase electrofishing removal of male SMB from nests has proven effective.
High	- Experiment with alternate techniques to disrupt SMB nesting success.		Pending	X	X	X	X	X	E.g., a pressurized water stream has been proposed.
High	Establish must-kill regulations for NOP, SMB and WLY in Yampa basin.	CPW	Pending	X	X				A must-kill regulation will help change the perception that these populations and the resulting fisheries should be promoted, sustained or expanded.
High	Investigate benefits of Elkhead Reservoir releases to manage invasive fishes in Yampa River critical habitat.	PDO, LFL, CRWCD	Ongoing	X	X	X	X		During Summer 2011, releases used to extend mechanical removal (Surge) of SMB and NOP in middle Yampa River.
Med	Eradicate or control northern pike in Little Snake River near Baggs, WY.	WYGF & PDO	Ongoing	X	X	X	X		Adult northern pike confirmed in Little Snake River in WY near Baggs. Northern pike, assumed to have invaded from the Yampa River, threaten to establish prolific reproducing population in renovated wetland habitats, potentially creating an additional source population in the Yampa River basin.

ES-4a. Duchesne River Action Plan

4a	Activity – DUCHESNE R.	Who	Status	FY					Comments/clarification
Rank				14	15	16	17	18+	
High	Control escapement of SMB and WLY from Starvation Reservoir	UDWR, USBR, PDO	Pending	X	X	X			Otolith microchemical analyses indicate escapement by walleye into critical habitat in the Green River. UDWR will assess control / containment options by Dec. 31, 2013.
Med	Inventory fish populations in Duchesne River basin small reservoirs and ponds.	FWS, UIT, UDWR	Pending		X	X			Several small impoundments (e.g., Bottle Hollow Reservoir) contain nonnative warmwater fishes.
Med	- Evaluate escapement for problematic additions of invasive fishes into Green River critical habitat.		Pending		X				Screen to control fish escapement installed at Elder Pond, which also controls escapement from Bottle Hollow.
Med	- Modify situation as needed if fish escapement proves problematic (fish populations, screen, etc.).		Pending			X	X		Presence and escapement of invasive fishes (NOP, SMB, etc.) of concern.
High	Reduce/maintain nonnative piscivore densities in Duchesne River below propagule threshold.		Pending					X	Spawning by SMB and WLY in Duchesne mainstem may be contributing these species into Green River critical habitat. Consultation/ coordination with the Tribe will likely be required.

ES-5a. White River Action Plan

5a	Activity – WHITE RIVER	Who	Status	FY					Comments/clarification
Rank				14	15	16	17	18+	
High	Implement integrated approach to eradicate or reduce smallmouth bass population in White River to below propagule threshold.	FWS, CPW, UDWR	Ongoing	X	X	X	X		Use of boat/raft electrofishing and an electric seine have been used to remove smallmouth bass to date.
High	- Adopt must-kill regulation to help reduce/control SMB. Establish same for NOP in case this species invades.	CPW	Pending	X	X				SMB density in White River below Taylor Draw Dam and downstream remains high and may readily increase SMB numbers downstream into Utah.
Med	- Use otolith microchemistry to investigate origin of SMB in White River below Taylor Draw Dam.	CPW, PDO, CSU	Pending		X				Likely source appears to be immigration from Green River and subsequent reproduction. Analyses of otoliths may reveal other source(s).
High	- Implement harvest incentive to promote angler removal of smallmouth bass.	PDO	Pending		X	X	X		Efficacy of an incentive program currently being discussed. Bounty for SMB would likely need to be implemented and evaluated for five years.
High	Monitor White River basin for occurrence of invasive fishes and eradicate/isolate as required.	CPW	Ongoing	X	X	X	X	X	Reservoirs upstream of Taylor Draw Dam have received illegal introductions of fishes (e.g., black crappie in Avery, NOP in Kenney Res. and Rio Blanco Lake).
High	Designate White River as Native Fish Conservation Area (NFCA) for warmwater native fishes.	UDWR, CPW, BLM, UIT	Pending					X	UDWR has been discussing NFCA designation with a White River work-group for the White River within UT.

ES-6a. Colorado River Mainstem Action Plan

6a	Activity – COLORADO RIVER	Who	Status	FY					Comments/clarification
Rank				14	15	16	17	18+	
High	Eradicate or suppress NOP and SMB in Rifle Gap Reservoir to eliminate this source of these species in Colorado River critical habitat.	CPW, PDO	Ongoing	X	X	X	X	X	NOP and WLY have been confirmed by otolith analyses to reach critical habitat from Rifle Gap Reservoir. NOP were illegally introduced into Rifle Gap. SMB escapement from Rifle Gap is also likely source of this invasive species with in critical habitat of the upper Colorado River. CPW constructs coanda screen in reservoir outlet channel in 2013.
High	- Evaluate function, reliability, maintenance, and vandalism of screen in Rifle Creek below dam at Rifle Gap for five years.		Ongoing	X	X	X	X		This timeframe is required by the FWS' ESA consultation (6/21/2011), to ensure screen's function in controlling escapement.
High	- Restocking of Rifle Gap restricted to Compatible list species., including sterile hybrids		Pending					X	May include sterile warmwater fish (e.g., triploid walleye).
Med	Confirm presumed lack of connection between Harvey Gap Reservoir and Colorado River mainstem by use of semi-buoyant gelatinous beads. Lack of connection may supersede need for screen to control escapement.	CPW, PDO	Pending	X	X				Harvey Gap Reservoir contains several warmwater sport fish species, including northern pike, smallmouth bass, walleye, etc., that would be a concern if this reservoir is a source of these species in critical habitat,
Med	- Eradicate or suppress NOP and SMB in Harvey Gap Reservoir	CPW	Pending	X	X	X	X	X	Harvey Gap Reservoir contains illegally established NOP.
Med	Periodically inventory other impoundments in Colorado River drainage to determine presence or escapement of invasive fishes.	CPW	Annual	X	X	X	X	X	Other reservoirs in basin have been illegally stocked and this activity may result in establishment of additional populations of NOP or SMB.
Med	- Eradicate Non-compatible list species in Gypsum Ponds.	CPW	Pending	X	X	X			Gypsum ponds illegally stocked with SMB, and other warmwater fishes.

ES-6b. Colorado River Mainstem Action Plan (continued).

6b	Activity – COLORADO RIVER	Who	Status						Comments/clarification
Rank				14	15	16	17	18+	
High	Maintain removal of SMB in mainstem Colorado River.	FWS, CPW	Ongoing	X	X	X	X	X	SMB are established in mainstem Colorado; conditions may occur that allow SMB to expand in distribution and abundance.
High	Maintain removal of LMB in mainstem Colorado River.	FWS, CPW	Ongoing	X	X	X	X	X	LMB have increased in abundance, but appear to have low survival and few adults are captured. LMB removal in conjunction with control efforts for SMB may be sufficient to control LMB, but ongoing removal and monitoring will reveal if additional effort or research are required.
High	Implement integrated approach to eradicate/remove NOP in Colorado River basin, including its mainstem, floodplain nursery habitats and reservoir source populations.	CPW, FWS	Ongoing	X	X	X	X		NOP are now established in both the Colorado River near Rifle and in gravel pits upstream and will likely invade downstream, rapidly increasing their distribution and abundance if allowed to persist. NOP have also been reported in Connected Lakes near Grand Junction.
High	- Discontinue installation of "notches" for reclaiming gravel pits to restore flooded bottomlands and wetlands until northern pike are eradicated in the Colorado River.	FWS	Complete						Notching of dikes and berms separating gravel pits from the mainstem Colorado River was intended to facilitate in-filling through sedimentation to restore riverine ecosystem function for native aquatic and terrestrial species. NOP may exploit these habitats for reproduction, recruitment, feeding, and year-round habitat.
High	Replace and maintain spillway barrier net at Highline Lake.	CPW	Ongoing	X	X	X	X	X	Net replaced about every five years; due for replacement. Maintenance ongoing.
Med	- Monitor below Highline dam to ensure that SMB do not escape.	CPW	Ongoing	X	X	X	X	X	SMB established in reservoir.
High	- Perform outlet releases during hypoxic period mid- to late-summer.	CPW	Ongoing	X	X	X	X	X	Minimizes need to screen discharge from outlet as fish avoid oxygen depleted water. CPW developed a sock net attachment for the outlet works in 2013, which could be deployed during future outlet releases.

ES-6c. Colorado River Mainstem Action Plan (continued).

6c	Activity – COLORADO RIVER	Who	Status	FY					Comments/clarification
Rank				14	15	16	17	18+	
Low	Investigate most problematic sources of floodplain ponds contributing nonnative fishes into critical habitat.	TBD	Pending					X	The abundance of some warmwater nonnative fishes (e.g., LMB) may increase in critical habitat following high water events that connect floodplain ponds/habitats. Whitledge et al. (2006, 2007) previously examined this mechanism in the Grand Valley and these techniques remain available.
Med	Investigate origins of nonnative fishes in upper (NOP) and lower (WLY) reaches and associated habitats of the Colorado River.	UDWR, CPW, CSU	Ongoing	X	X				NOP and WLY have increased in abundance in the upper and lower reaches of the Colorado, respectively, in recent years. Information about the source of these fishes may facilitate their control.
Med	Adopt must-kill regulation for SMB, WLY and striped bass in Lake Powell extending upstream from the confluence with the Dirty Devil River Arm of the reservoir.	CPW, UDWR, WYGF	Pending	X	X	X	X		In lieu of must-kill regulations reservoir-wide, a spot regulation near the site of upstream emigration may be beneficial to help reduce number of fish moving up into riverine critical habitat.

ES-7a. Gunnison River Mainstem Action Plan

7a	Activity – GUNNISON RIVER	Who	Status	FY					Comments/clarification
Rank				14	15	16	17	18+	
High	Maintain Gunnison River as nonnative predator-free system to facilitate maintenance of native aquatic community for achieving and sustaining recovery of endangered fishes.	CPW, FWS	Ongoing	X	X	X	X	X	Nonnative predators can limit restoration of Colorado pikeminnow densities if they occur even in relatively low numbers as large-bodied individuals which reduce carrying capacity for adult Colorado pikeminnow.
High	- Eliminate predatory NOP in Paonia Reservoir to help prevent their escapement into/ establishment in critical habitat.	CPW, PDO	Complete						This was performed in October 2012. I&E and enforcement required to help prevent illegal reintroduction of pike into this reservoir. CRRP to cost-share rotenone.
High	- Eliminate illegally stocked NOP, WLY and SMB in Crawford Reservoir to prevent their escapement into critical habitat.	CPW, PDO	Pending	X	X				Escapement potential is high and reservoir is not screened. Trout stocking has been discontinued by both state and federal hatcheries due to excessive predation by northern pike. Fish population needs to be reclaimed and replaced with sport fishery that is compatible with recovery.
Med	- Implement must-kill regulations for non-approved nonnative predatory fishes in Gunnison River reservoirs (e.g., Crawford, Juniata, Paonia, and Ridgeway Reservoirs; e.g., NOP, SMB, and WLY).	CPW	Pending	X	X				Must-kill regulations would help send message about incompatibility of nonnative piscivores with native and endangered fish management priority in Gunnison River. Gunnison remains as last major tributary in the UCRB that has not been invaded with invasive piscivores.
Low	- Eradicate illegally established SMB and WLY in Juniata Reservoir.	CPW, PDO	Pending					X	Juniata outlet into irrigation ditch that connects to Kannah Creek has been screened, but screen function or extent of escapement by SMB or WLY unknown.

ES-8a. Dolores River Action Plan

8a	Activity – DOLORES RIVER	Who	Status	FY					Comments/clarification
Rank				14	15	16	17	18 +	
Med	Control SMB in Dolores River basin to minimize risk of them reaching Colorado River critical habitat.	CPW	Pending	X	X	X			Combination of invasive SMB, abundant crayfish, and low flows suggest that SMB from the Dolores River can be expected to spread downstream, possibly reaching critical habitat in the Colorado River.
Med	- Eradicate illegally introduced SMB in Miramonte Reservoir.	CPW, PDO	Complete						CPW completed rotenone application in fall 2013. CRRP contributed to rotenone costs.
Low	- Actively remove SMB from Dolores River mainstem.	CPW, PDO	Pending						Proposal to send Recovery Program crew to assist with removal of SMB from Dolores River within concentration above Disappointment Creek was discussed with CPW, BOR and LFL in 2012.
Med	- Manipulate release from McPhee Reservoir to disadvantage SMB	CPW, BR	Pending						
Med	Implement must-kill regulations for illegally stocked predatory fishes in McPhee Reservoir (e.g., NOP and WLY).	CPW	Pending	X	X				Adopt must-kill regulation to help suppress numbers of predatory species in source population in reservoir. Reinforce message to discourage illegal stocking or re-stocking of these predatory fishes.
Low	Adopt must-kill regulation for SMB near dam at McPhee Reservoir reduce predator density near point(s) of water release (i.e. outlets, spillway) to reduce the risk of escapement.	CPW, UDWR, WYGF	Pending	X	X	X	X		In lieu of must-kill regulations reservoir-wide, spot regulations near the site of escapement/entrainment may be beneficial to help reduce number of fish moving up into riverine critical habitat

Upper Colorado River Basin Nonnative and Invasive Aquatic Species Prevention and Control Strategy

By: Nonnative Fish *ad hoc* Committee (Patrick Martinez, Krissy Wilson, Pete Cavalli, Harry Crockett, Dave Speas, Melissa Trammell, Brandon Albrecht, Dale Ryden)

Purpose

This Upper Colorado River Basin Nonnative and Invasive Aquatic Species Prevention and Control Strategy (Basinwide Strategy) was developed by the Upper Colorado River Endangered Fish Recovery Program (Recovery Program) in response to existing and expanding concerns and populations of nonnative aquatic species within critical habitat of the upper Colorado River basin (UCRB). Recovery Goals documents for the four endangered fishes in the UCRB, bonytail *Gila elegans*, humpback chub *G. cypha*, Colorado pikeminnow *Ptychocheilus lucius*, and razorback sucker *Xyrauchen texanus*, specify the threat of diseases and predation by nonnative species, and the adequacy of existing regulatory mechanisms as factors in the listing of these endangered species and as criteria that must be evaluated in the recovery and de-listing process (USFWS 2002a, 2002b, 2002c, 2002d). Presently, the Recovery Program is expected to have sufficiently addressed the de-listing criteria per the Endangered Species Act (ESA) such that the recovery goals for these endangered fishes can be achieved and sustained by 2023 (CRRP 2009a). Thus, there is an urgency to achieve significant progress toward eliminating or reducing biological threats to the endangered fishes. This will require that Recovery Program partners expeditiously implement practices, policies, regulations, and enforcement to prevent or minimize the appearance of new threats or the expansion or recurrence of existing threats.

Strategic Plan Need and Justification

A previously adopted Nonnative Fish Management Policy (Policy; CRRP 2004a) recognized that management of nonnative fish was one of many adaptive actions required to secure native fish communities, attain recovery of endangered fishes, and maintain populations and conditions that would allow recovery to persist. The Policy advised that nonnative fish management would initially follow an experimental approach, but that this process should not unduly delay timely and effective actions. A subsequent directive regarding Nonnative Fish Management in the Yampa River Basin (Directive; King 2006) stated that the approach to nonnative fish control should be highly proactive. The Directive recommended a thorough assessment of efforts to control nonnative fish in the Yampa River and development of a stronger adaptive management framework to expedite nonnative fish control. It recognized that the Recovery Program would be required to undertake substantial and expensive actions based on the hypothesis that native fish would benefit from these projects and that the actions would be adjusted if the benefits were not realized. The Yampa River Nonnative Fish Control Strategy (YAR Strategy; Valdez et al. 2008) was prepared in response to the 2006 Directive. The YAR Strategy sought to identify nonnative fish control actions of sufficient scale and intensity that would achieve measurable fish responses over the shortest possible timeframe. Following an assessment of existing control efforts, actions would be refined and updated to advance nonnative fish control in the Yampa River.

This Basinwide Strategy incorporates elements of the YAR Strategy and builds on its guidance to promote and achieve enduring nonnative aquatic species control basin-wide within the UCRB. In addition, this Basinwide Strategy seeks to encourage and facilitate quality sport fisheries that are compatible with the goals of achieving and sustaining recovery of endangered fishes and that allow the maintenance and preservation of a relatively intact aquatic community consisting of species native to the warmer reaches of streams and rivers at the lower elevations in the UCRB, including the three-species of larger-bodied, non-endangered fishes (roundtail chub *Gila robusta*, bluehead sucker *Catostomus discobolus*, and flannelmouth sucker *C. latipinnis*; UDWR 2006a, 2006b). While salmonids are considered to be highly compatible with the goals of restoring endangered fishes as part of a functioning native aquatic community in the UCRB, nonnative, nonsalmonid species pose varying degrees of threat to the various life stages of native fishes. It is acknowledged that the introduction of nonnative piscivorous fishes in the Colorado River basin is generally a consequence of introductions of sport fish (Kappenman et al. 2012). However, to promote sport fishery management that is compatible with endangered fish recovery in the UCRB, acceptable nonsalmonid fishes will include those species or hybrids which are least likely to proliferate in the warmer streams and rivers of the UCRB and that display a reduced capacity to interact negatively (prey, compete or hybridize) with native fishes due to their limited adaptability or invasive impacts in lotic, warmwater habitats.

Native fish communities which are less complex, as in the Colorado River basin (CRB), may be more susceptible to invasions (Moyle and Light 1996; Mitchell and Knouft 2009). An altered riverscape and the interaction of native and nonnative species with non-adapted and competing life histories has contributed to what may be the largest expansion of nonnative fishes and displacement of native fishes in a North America river basin (Olden et al. 2006; Kappenman et al. 2012). Over 40 nonnative fish species now occur in the UCRB, compared to 14 native fish species (Valdez and Muth 2005). Major ecological effects associated with nonnative fish introductions include predation, habitat degradation, competition for resources, hybridization or disease transmission (Gozlan et al. 2010); however, recent efforts in the UCRB have focused on reducing the numbers and negative impacts of invasive predatory fishes in critical habitat Increases in abundance and distribution of some nonnative fish species during drought conditions in the last decade have prompted aggressive management of these species and the need for a coordinated strategy for the UCRB. Nonnative fishes can attain higher density, biomass, and annual production than the native species they replace, likely through changes in ecosystem function (Benjamin and Baxter 2010). Nonnative fishes can be numerically predominant in riverine fish habitats and communities, and negative interactions with certain warmwater nonnative aquatic species (particularly predatory sport fishes) have contributed to declines in native fish populations the southwestern United States (Carlson and Muth 1989; Marsh and Douglas 1997; Clarkson et al. 2005; Anderson and Stewart 2007; Johnson et al. 2008; Propst et al. 2008). The most problematic nonnative fish species in the basin have been identified as northern pike, smallmouth bass and channel catfish *Ictalurus punctatus*, although other nonnative percid, ictalurid, cyprinid, centrarchid and catastomid species continue to be problematic (Johnson et al. 2008). Areas where control is required for one or all three of these invasive predators in the UCRB currently include portions of the Colorado, Dolores, Green, Gunnison, San Juan, White, and Yampa rivers within the states of Colorado, New Mexico and Utah.

The dramatic decline of native fishes in the Yampa River provides a stark example of the cumulative detrimental impacts of an increase in the number and abundance of nonnative aquatic species, particularly increases in the range and abundance of invasive species including northern pike and smallmouth bass, and virile crayfish *Orconectes virilis* (Martinez 2012). The Yampa River has been described as the "crown jewel" of the UCRB due to its formerly robust native fish populations (Johnson et al. 2008) and its comparatively unregulated hydrograph (Roehm 2004; Stewart et al. 2005). It contains designated critical habitat for the four endangered fishes of the UCRB. In recent decades, the Yampa River has been progressively invaded by nonnative species, altering the native aquatic community and food web and increasing the threat of invasive impacts to native and endangered fishes (Johnson et al. 2008; Martinez 2012). Examples of these threats include the detection of Asian tapeworm *Bothriocephalus acheilognathi* (Ward 2005), hybridization between native sucker species and nonnative white sucker *Catostomus commersoni* (Douglas and Douglas 2003), and predation or apparent competition with and hyperpredation on native and endangered fishes (Johnson et al. 2008; Hawkins et al. 2005; Bestgen et al. 2008; Martin and Wright 2010; Martinez 2012). Endangered Colorado pikeminnow (*Ptychocheilus lucius*) have steadily declined in the Yampa River (Bestgen et al. 2007a), despite pikeminnow increases in four other major population areas in the Green River basin (Bestgen et al. 2010).

Past efforts to control nonnative fish in the UCRB have been hesitant and measured in response in some instances due to angler or agency opposition to the removal of popular sport fishes from locations contributing these species into critical habitat. This delayed and incremental implementation of eradication or control efforts has allowed species such as northern pike and smallmouth bass to become ecologically entrenched in the Yampa River (Martinez 2012) by foregoing the opportunity for early intervention. The increase in distribution, abundance and severity of the impact of these species on native and endangered fishes has greatly increased the cost of reducing their populations in the Yampa River, and possibly elsewhere, will require increased levels of removal (Haines and Modde 2007; Breton et al. 2013). The likelihood of success in applying this increased effort and expense to suppress these problematic populations will be improved by employing presently un- or under-utilized techniques. New and repetitive introductions of nonnative species through escapement from off-stem habitats (Fitzpatrick and Winkelman 2009; Wolff et al. 2012) or via unauthorized movement by humans (Johnson et al. 2009) continues to transform the food web of the Yampa River into one dominated by nonnative species that is less likely to serve as a stronghold for native and endangered fishes (McGarvey et al. 2010; Martinez 2012).

It has become imperative that preventive, eradication and control measures be diligently, vigorously, and more rapidly applied to restore the native aquatic community in the Yampa River and to prevent similar invasive impacts from occurring in any other rivers or tributaries in the UCRB. While significant reduction or eradication of some species may be impractical or intractable in some UCRB habitats (e.g., smallmouth bass in Flaming Gorge and McPhee reservoirs or Lake Powell), avoiding management that exacerbates existing threats or problems due to nonnative fishes is paramount. Elucidating the ecological consequences, cumulative management costs, and resource ramifications of the invasive impacts by problematic species is intended to reinforce the urgency to better prevent increases in their range or abundance, and to intensify their reduction, control, or eradication as necessary and feasible.

Supporting Documents

Control of nonnative fish species to alleviate competition with and/or predation on rare fishes is identified as a necessary management action in all major recovery plans in the Southwestern U.S., including those of the Gila River Basin (DFT 2003; Carman 2006), the Lower Colorado River Basin (Minckley et al. 2003), the Glen Canyon Dam Adaptive Management Program (GCDAMP 2006; Coggins and Yard 2010), the Virgin River Resource Management and Recovery Program (UDNR 2002), the San Juan River Basin Recovery Implementation Program (SJRIP 1995) and the Upper Colorado River Endangered Fish Recovery Program (USFWS 1987). Recovery goal documents for the four endangered fishes in the UCRB bonytail *Gila elegans,* humpback chub *Gila cypha,* Colorado pikeminnow *Ptychocheilus lucius,* and razorback sucker *Xyrauchen texanus* Recovery Goals (USFWS 2002a, 2002b, 2002c, 2002d) identified predation or competition by nonnative fish species as a primary threat to the continued existence or the reestablishment of self-sustaining populations of these endangered fishes.

The nonnative fish management Policy adopted in 2004 by the Recovery Program and its partners identified nonnative fish management as one of several broad categories of activities necessary to achieve and maintain recovery of the endangered fishes (CRRP 2004a). Management of nonnative fishes was described as an adaptive process, and that once strategies were developed, they would be evaluated and revised based on results of research and monitoring. The Policy also recognized that nonnative fish species targeted for management may have sport fish value with the angling public, and that the dual responsibilities of State and Federal fish and wildlife agencies to conserve listed and other native species while providing for recreational fishery opportunities would be considered in nonnative fish management strategies developed and implemented by the Recovery Program. Finally, the Policy recognized that agency and public understanding of the purpose and scope of nonnative fish management actions by the Recovery Program was critical to the success of the effort, which necessitates active and adaptive information and education programs.

Key foundational documents regarding the need and strategies to control nonnative fish in the UCRB that were developed and/or are recognized by the Recovery Program include Hawkins and Nesler (1991), Tyus and Saunders (1996), Lenstch et al.

(1996), and SWCA Inc. (2002). Guidelines for development of nonnative fish management actions common to all these documents include:

1. Assessment of impacts of nonnative aquatic species on native fish populations, including problem species and probable impact mechanisms.

2. Identify spatial extent of impacted populations and potential nonnative source systems; prioritize areas by severity and cost/benefit ratios.

3. Development of coordinated nonnative fish control strategies; identify potential sport fishing conflicts.

4. Identification and use of effective nonnative control methods.

5. Development of programs to monitor results of nonnative control measures.

6. Assure information, education, and outreach programs are in place to communicate intentions and findings to the public.

The 2007-2012 Aquatic Nuisance Species Task Force Strategic Plan (ANSTF 2007) and the 2008-2012 National Invasive Species Management Plan (NISC 2008) share similar definitions and goals. Nonnative species may harm or have the potential to harm the environment, economy, or human health. Species possessing or demonstrating this potential to inflict invasive impacts are known as invasive species (NISC 2008). Both plans stress the distinction between invasive species prevention and control and emphasize the need for research efforts, cross-jurisdictional policies, and education programs to combat invasive species. Key components from the goals of these plans are modified below for application in this Basinwide Strategy:

1. Prevention is the first line of defense and seeks to prevent the introduction and establishment of nonnative aquatic species or their dispersal through early detection and a rapid containment/eradication response to halt/reduce their invasive impact to the native aquatic food web of the UCRB.

2. Apply control techniques and implement management strategies for nonnative aquatic species to slow their spread and reduce their distribution, abundance and invasive impacts to allow preservation/restoration of the native aquatic food web of the UCRB.

3. Conduct research on the methods and scale required to effectively monitor populations of nonnative aquatic species, assess their ecological impact, contain their distribution, control, reduce or eradicate their populations, mitigate their impact to native species and to manage mixed assemblages of native and nonnative species.

4. Encourage adoption of policies and educational programs across agencies and jurisdictional boundaries that emphasize prevention of the intentional or illegal introduction, establishment, dispersal, or perpetuation of nonnative aquatic species which pose demonstrate or pose a high risk of invasive impacts to the native aquatic food web by identifying and addressing cross-jurisdictional weak links.

Evolution of the <u>Basinwide Strategy</u>

In addition to the evolution of policy to guide the implementation of nonnative fish control in the UCRB, control efforts also evolved through a series of nonnative fish control workshops. The first of these, hosted by the USFWS on 27 March 2001in Grand Junction, focused on strategies to control northern pike in the Yampa River (Martinez 2001). Annual Nonnative Fish Workshops, hosted by the Recovery Program in December in Grand Junction, have provided data assessments and adaptive management since 2002 to determine future nonnative fish control strategies, including changes to the list of target nonnative fish species, geographic scope of management areas, and methods employed (CRRP 2002, 2003, 2004b, 2005, 2006, 2007, 2008, 2009b, 2010, 2011b, 2012b). The Smallmouth Bass Summit, hosted by CDOW on 28-29 March 2005 in Grand Junction, sought to identify and recommend strategies to expedite removal of smallmouth bass in the UCRB to control their proliferation/invasiveness and their negative impacts/impediments to native fish conservation and endangered fish recovery (Martinez 2006). The annual Nonnative Fish Workshops involved interactive sessions among biologists and managers to develop creative approaches for improving efficiency of nonnative fish control. Management of nonnative fish species in the UCRB has followed an experimental approach to develop effective strategies and identify the levels of management necessary to minimize or remove threats to the endangered fishes. The annual workshops frequently resulted in recommendations for revisions to the subsequent year's workplan on a project-by-project basis.

In January 2008, a Nonnative Fish Subcommittee (NNFSC) of the Biology Committee was tasked with the development of the Yampa River Strategy (Valdez et al. 2008). The NNFSC was also responsible for the more generalized task of reviewing and making recommendations to the Recovery Program's Biology Committee (BC) on various nonnative fish management issues that the BC otherwise didn't have time and/or expertise to accomplish, such as compiling recommendations from past workshops, working with state wildlife officials to review and resolve specific nonnative fish issues, and organize the nonnative fish workshops. At the 18-19 August 2008 BC meeting in Salt Lake City, the NNFSC was tasked with ranking the recommendations generated by Recovery Program participants at past Nonnative Fish Workshops (NNFSC 2008). The NNFSC suggested and the BC agreed that when prioritized, these recommendations would ultimately serve as the foundation for an UCRB <u>Basinwide Strategy</u> which would be patterned after the YAR Strategy (Valdez et al. 2008).

On 30 June and 1 July 2010 in Grand Junction, the NNFSC reviewed the categorization and prioritization of the Nonnative Fish Workshop recommendations and strategies. It was agreed that the <u>Basinwide Strategy</u> should address nonnative aquatic species rather than just fish due to emerging concerns about invasive invertebrate species, thus the title was changed to Upper Colorado River Basin Nonnative and Invasive Aquatic Species Prevention and Control Strategy. In addition, it was determined that several items previously identified as preventive strategies were more appropriately categorized as control measures. Prevention includes measures directed at the preemption of invasive species introduction and their impacts, while the control category includes actions undertaken after they have become established or problematic. National invasive species plans illustrate this distinction and provide a basis for a stronger approach to prevention of nonnative aquatic species and their potential invasive impacts to native aquatic communities. This Basinwide Strategy is guided by principles of invasive species biology, existing invasive species policy, and examples of best management practices for avoiding invasions and impacts by nonnative aquatic species.

This Strategy is based on the following assumptions:

1. Nonnative aquatic species can inflict invasive impacts on native aquatic communities through predation, competition, hybridization or habitat alteration and threaten recovery of the endangered fish species.

2. Nonnative aquatic species are not the only invasive threat to native and endangered fish species, but prevention, reduction or eradication of problematic populations of nonnative species will benefit endangered fishes and its native aquatic community.

3. Removal strategies may not eradicate problematic nonnative aquatic species from the UCRB and may require multiple, adaptive or sustained actions through time.

4. Identifying and controlling sources of nonnative aquatic species in the UCRB will improve efficiency and effectiveness of preventing invasive impacts to the native aquatic community required to achieve and sustain recovery of endangered fishes.

5. The UCRB is a complex and dynamic ecosystem and the threat of nonnative aquatic species may change over time, including those species posing the greatest risk of invasive impacts to the native aquatic community and endangered fish recovery.

6. Suppression of nonnative species and their invasive impacts may reveal additional environmental limitations, such as habitat or water quality, that may also be limiting endangered fish recovery and would require remediation.

Goal and Objectives

The goal of this Basinwide Strategy is to reduce the negative ecological impact that problematic nonnative aquatic species currently pose or may pose for the native aquatic community in critical habitat so that they no longer are an impediment or threat to the recovery of endangered fishes in the UCRB. The objectives of this Basinwide Strategy are to:

1) Implement control actions for existing, problematic nonnative predatory fish species (e.g., northern pike *Esox Lucius*, smallmouth bass *Micropterus dolomieu*, and walleye *Sander vitreus*) to expedite their reduction or eradication from source habitats or within critical habitat.

2) Prevent the introduction of additional invasive aquatic species in the UCRB and the expansion in distribution or abundance of the currently existing problematic nonnative aquatic species in the UCRB.

3) Adaptively identify, fund, and implement currently available or new management actions of sufficient scale and intensity to achieve reductions in problematic populations of nonnative aquatic species over the shortest plausible timeframe.

4) Verify the sustained reduction of problematic fish populations in source habitats and within critical habitat to facilitate maintenance of relatively intact native aquatic species community to promote endangered fish recovery.

5) Facilitate the management of nonnative aquatic species for recreational, research, or commercial purposes that are compatible with endangered fish recovery.

6) Implement policies and practices that ensure enduring control of invasive species and sufficiently remove the threat of problematic nonnative aquatic species in critical habitat and associated waters to help facilitate, achieve, and sustain recovery of endangered fishes.

7) Transfer primary management of nonnative aquatic species from the Recovery Program back to the states of the UCRB by 2023.

Implementation and Coordination

This Basinwide Strategy will be implemented via the Recovery Implementation Program Recovery Action Plan (RIPRAP; Management Committee 2012a). The RIPRAP was developed, and is modified annually, by Recovery Program partners using the best, most current information available and the recovery goals for the four endangered fish species (USFWS 2002a, 2002b, 2002c, 2002d). It identifies specific actions and time frames currently believed to be required to recover the endangered fishes in the most expeditious manner in the UCRB. The RIPRAP serves as the Recovery Program’s short-term and long-term plan, and includes dates for accomplishing specific actions over the next 5 years and beyond. The RIPRAP provides a measure of accomplishment that the U.S. Fish and Wildlife Service uses to determine if the Recovery Program can continue to serve as a reasonable and prudent alternative for projects undergoing Section 7 consultation to avoid the likelihood of jeopardy to the continued existence of the endangered fishes as well as to avoid the likely destruction or adverse modification of critical habitat. Specific management actions or strategies (tasks) to be included in the RIPRAP come from:

1) the Nonnative Fish Subcommittee' (NNFSC) summarization, categorization, and prioritization of the collective analyses, discussion and annual modifications to nonnative fish control efforts resulting from the 2002-2009 Nonnative Fish Workshops (CRRP 2002, 2003, 2004b, 2005, 2006, 2007, 2008, 2009b; these are identified as ***NNF0209***); and

2) recent items resulting from presentations and discussions by the Recovery Program's Nonnative Fish Coordinator, including comments received on the draft Basinwide Strategy (dated September 2011), at Recovery Program meetings (Biology, Management, and Implementation committees, and the Nonnative Fish Subcommittee), and from the Nonnative Fish Workshops (CRRP 2010, 2011b, 2012b; these are identified as ***NNF1012***).

Management Strategy and Actions

The specific management actions and strategies from these two time periods were combined and incorporated into five major sections in this Basinwide Strategy.

I. Prevention

II. Eradication, Control, and Management

III. Research and Monitoring

IV. Policy and Enforcement

V. Information and Education

More detailed information pertinent to aspects in the first four sections (I-IV) is provided in Appendices A-H. These appendices provide expanded reviews of available literature, data, or rationales for specific topics or techniques.

Recommendations for Sections (I-V) of this Basinwide Strategy are contained in the Executive Summary (ES) in Tables ES-1a through ES-8a. Due to the specific nature or site location of some tasks, not all tasks listed in Tables ES-1a through ES-8a are specifically mentioned within sections I-V below. Tables ES-1a through ES-8a emulate those in the RIPRAP's Action Plans. The column for "rank" indicates the level of priority, either High, Medium (Med), and Low, initially assigned to each task or strategy. For many of these tasks/strategies, the ranking is further described in the Basinwide Strategy. The "who" column identifies the lead agency (listed first) and any cooperating agency(s). The status column identifies whether a task or strategy is ongoing, pending, to be performed annually, or is completed. Each task is scheduled to be performed in a specific year or years. The Recovery Action Plans for the General category (Tables ES-1a to ES-1o) are organized according to the five sections: I. Prevention; II. Eradication, Control, and Management; III. Research and Monitoring; IV. Policy and Enforcement; and V. Information and Education. The remaining Recovery Action plans (Table ES-2a to ES- 8a) contain tasks and strategies for the Colorado and Green River sub-basins and their major tributaries.

The ten-year span of this timeline reiterates the urgency to implement these strategies and management actions to secure and sustain recovery by 2023, the current sunset date for the Recovery Program when the primary management of the recovered species and their habitat would revert back to the states of the UCRB. Given the urgency involved, flexibility will be required for implementation based on availability of funds, personnel, cooperative involvement and agreements, or technology. However, failure to implement these strategies will likely diminish the effectiveness of other recovery strategies (e.g., flow management, habitat restoration, endangered fish stocking) or the likelihood that a community of native aquatic species needed to promote and perpetuate recovery could be sustained. The Basinwide Strategy will continue to follow the experimental approach currently employed by the Recovery Program to combat problematic nonnative species, assess distributions, estimate abundances and reduce threats. Adaptive management principles will continue to be utilized where appropriate. This strategy describes available tactics and actions that help achieve the levels of management necessary to minimize or remove threats to the endangered fishes. Data and information collected will continue to be evaluated annually to determine and refine nonnative fish management actions under the principles of adaptive management. This process has already begun and will not unduly delay timely and effective actions to minimize or remove the nonnative threat to the endangered fishes.

The downlisting of UCRB endangered fishes will require meaningful reductions in the abundance, distribution, and sources of nonnative aquatic species and their negative ecological impact to the native aquatic community to remove the impediment they pose for recovery. It could be argued that the pace of progress has been too slow, particularly as species known to be problematic in one sub-basin begin to invade in another sub-basin. This Basinwide Strategy is intended to accelerate progress to remove the invasive impacts and threat of nonnative fishes in the UCRB to an extent that they are no longer an impediment to recovery over the next decade. The current approach needs to expand to incorporate concepts of invasive species prevention. The probability of success will also be improved through a diversified approach employing more of the available techniques, including treating source populations, incorporating the concept of propagule pressure as a measures of success, and better messaging (e.g., “must kill” regulations, a Stop Illicit Introductions campaign, etc.). Many of the changes in the current approach to nonnative fish management in the UCRB need to be made through changes to State policies and regulations. This Basinwide Strategy capitalizes on lessons learned during the past two decades of field experiences, and on the information exchanged in Nonnative Fish Workshops in the past decade to provide guidance to implement the changes in policies and practices needed to reduce the impacts and threats of nonnative aquatic species in the UCRB.

I. Prevention

The cornerstone of native aquatic species preservation and recovery in the UCRB must become the prevention of new nonnative aquatic species of an unknown or demonstrated risk of invasion into the basin and the further spread of potentially or demonstrably invasive species that are already present (Vander Zanden and Olden 2008; Vander Zanden et al. 2010; Cucherousset and Olden 2011). Preventing the introduction and spread of nonnative aquatic species that may prove invasive is far more environmentally and fiscally desirable than undertaking control or eradication efforts after their arrival and establishment (Cucherousset and Olden 2011; Gherardi et al. 2011). Due to their proliferative potential, once an invasive species becomes established, eradication is often essentially impossible and control typically requires long-term and expensive efforts for an uncertain outcome (Pimentel et al. 2000; Simberloff 2003; Mueller 2005; Johnson et al. 2009; McIntosh et al. 2010). Increasingly, preventing introductions of new species (Horan and Lupi 2005) is necessary to help recovery and preserve native fishes in the UCRB. Further, stopping the replenishment of existing nonnative species populations that exist in or may reach critical habitat must be aggressively addressed because populations of invasive species are more likely to establish if they are repeatedly introduced (Perrings et al. 2002). Implementing principles and protocols for preventing the introduction of new invasive species or the further spread or reinvasion by nonnative species which have demonstrated invasive impacts in the UCRB is recommended as "**high priority**" (NNFSC 2008, ***NNF1012***).

Stocking Procedures

The foremost document currently providing a prevention strategy for nonnative aquatic fishes in the UCRB is the Procedures for Stocking Nonnative Fish Species in the Upper Colorado River Basin (Stocking Procedures; USFWS 2009). The purpose of the Stocking Procedures is to ensure that all future stocking of nonnative fish in the UCRB is consistent with recovery of the endangered fishes within critical habitat in Colorado, Utah and Wyoming (USFWS 2009). By controlling the introduction, stocking and escapement of stocked nonnative fishes, the Stocking Procedures seek to prevent negative impacts to the native aquatic community of the UCRB such that recovery of the endangered fish is not inhibited. Further, because fish stocking is an important component of recreational sport fisheries management and aquaculture, the Stocking Procedures apply to both the public and private sectors.

Continued adherence to the preventive measures in the Stocking Procedures regarding introductions of new species, the risk to native species posed by individual species already present in the basin, escapement and illegal introductions is a "**high priority**" (NNFSC 2008, *NNF1012*). Scrutiny of stocking, management and escapement by signatory agencies in reviewing Lake Management Plans will be required to maximize the effectiveness of the Stocking Procedures in protecting and preserving native aquatic communities, and in achieving and perpetuating endangered fish recovery. Incorporating redundancies of nonnative fish control measures contained in the Stocking Procedures should also promote prevention of invasive impacts by nonnative fishes. An example would be requiring both screens to minimize nonnative fish escapement from the stocking of sterile nonnative fishes to better ensure that access to or proliferation in critical habitat by nonnative fishes does not occur. An example is the requirement that ponds in the UCRB can only be stocked with certified triploid grass carp and those ponds must be screened to control escapement.

Questions regarding connectivity of ponds or reservoirs to riverine critical habitat may need to be resolved. One methodology includes the use of colored, semi-buoyant, gelatinous, biodegradable bead 3-6 mm in diameter (manufactured by Key Essentials, Inc.; Hedrick et al 2009). Detection of beads released in the outlets/tailraces of ponds/reservoirs near the tributary's confluence with a main-stem river containing critical habitat could inform decisions about connectivity under the conditions (flows, diversions) at that point in time. This method may need to be utilized periodically to better assess individual situations under variable conditions and during different seasons to confirm/refute connectivity. Other methods could include use of radio-telemetry or other passive sampling gear types.

Appendix B provides a review of current hybrid/sterile technology for fishes that might be proposed for stocking or management in the UCRB. This review of current technology for individual species or their hybrids is intended to serve as a guide for evaluating and approving stocking proposals. The development of reliable sterile induction methodologies and production capacity of hybrid/sterile sportfish has been recognized by the States as a serious factor limiting their use and is therefore considered a "high priority". If technologies for producing hybrids or inducing triploidy, or both have been developed for specific species, they should be employed in the UCRB and this shift in the management of nonnative warmwater sport fishes should be considered a "**high priority**" (***NNF1012***). Illegal stocking continues to undermine the strict implementation and preventive measures of the <u>Stocking Procedures</u> (Johnson et al. 2009). Stocking only hybrid/sterile predatory species may help reduce propagule pressure via this illegal activity. However, this growing problem in the UCRB must be swiftly addressed in a meaningful fashion and is discussed further in the **Policy and Enforcement** section. As an alternative, Upper Basin State Sportfish Coordinators have agreed to collaborate with other state and federal personnel to work through a process of identifying and ensuring health/AIS regulations are met in order to create a list of preferred vendors for sterile warm/coolwater fish species.

List for acceptable (Compatible) nonnative aquatic species

The adoption of a Compatible list of nonnative aquatic species for management or stocking in the UCRB is recommended to better promote prevention of invasive impacts to native aquatic communities. A Compatible list is a shorter, finite list of nonnative aquatic species with local, regional or global documentation over a period of time demonstrating their minimal adverse ecological impacts to sensitive or endangered native aquatic species or recreationally or commercially valuable aquatics species, or their habitats, given sound management. Compatible lists are proactive and preventive. If a species is not known to be widely beneficial and relatively innocuous, presenting minimal invasive risk, it cannot be included on the Compatible list. A Compatible list communications plan should recognize that these designations are subject to change (see text box).

<u>Compatibility with Recovery</u> – A species considered compatible with recovery of the endangered fish is, and will be, based on the best available scientific information. CRRP partners have learned that some species once thought compatible with recovery were later proven not to be (e.g. smallmouth bass).

A Compatible list for the UCRB would strive to accommodate most public, private, and commercial fishery management activities with some traditionally managed species that have proven compatible with native, endangered, recreational, and commercial fishery resources (Appendix C). However, some species that are currently present or managed in the basin (e.g., northern pike and smallmouth bass) would not automatically be included due to their severe threat or damage to native aquatic species. Development of a Compatible List for the aquarium and ornamental trade in the UCRB would also be prudent and is recommended (Padilla and Williams 2004). Requiring that any nonnative aquatic species to be introduced or routinely possessed, transported or stocked in the UCRB be included on a Compatible list established by expert review is recommended as "**high priority**" (NNFSC 2008, ***NNF1012***).

Non-compatible list for invasive aquatic species

In contrast to a list of nonnative aquatic species considered Compatible with recovery is a Non-compatible list. A Non-compatible list consists of invasive aquatic species with documented / demonstrated ecological impact to sensitive or endangered native aquatic species or recreationally or commercially valuable aquatic species, or their habitats on a local, regional or global scale. The present use of Non-compatible lists by various agencies having different jurisdictions within the UCRB could result in incomplete inclusion of potentially or demonstrably deleterious nonnative aquatic species due to varying perceptions, criteria, or priorities in identifying or categorizing nonnative aquatic species as invasive or worthy of prohibited status. Non-compatible lists tend to be reactive, continually adding nonnative aquatic species as they become recognized elsewhere as invasive, and may be slow to react until severe problems develop locally. This approach may also ignore local or regional invasive impacts by existing and traditionally managed species in the UCRB that have proven invasive, but continue to be promoted due to their popularity as sport fish or as prey of sport fish.

A Non-compatible list would remain useful (Simberloff 2006) and is recommended as a "**high priority**" for use in the UCRB (***NNF1012***). An UCRB Non-compatible list would include obviously egregious invasive species, including those species that are native to or stocked in other basins of UCRB states, but that are highly incompatible with endangered fish recovery or preservation of the native aquatic community in the UCRB. Regional Non-compatible lists of known problematic species, or of species of high risk, may help prevent the introduction of damaging species into new areas and contribute to the prioritization and justification of species targeted for eradication or control. In addition, an UCRB Non-compatible list of the worst-of-the-worst invasive species (Appendix C) would be useful for public and agency information and education. This overall approach will require coordination between state and federal agencies to promote, implement, and uniformly abide by the Compatible/Non-compatible list model to ensure consistency in the species included in the lists and its application to the public, commercial and private sectors. Recovery Program representation and participation in regional ANS meetings is recommended as a "**medium priority**" (***NNF1012***) to facilitate awareness of/access to information about progress in controlling existing ANS species, emerging invasive species, or techniques being applied to avert invasive species spread through rapid-response techniques or strategies.

Rapid response to new invaders or invasive species in new locations

Executing a rapid response to the appearance of new or recurring invasive species is a fundamental component of invasive species prevention (ANSTF 2007; NISC 2008). Intensive removal of northern pike was implemented soon after their numbers had increased in the Middle Green River in the late-1990s (Monroe and Hedrick 2008). It appears that this early intervention, maintaining a reduced level of removal in key habitats, and opportunistically removing northern pike as they are encountered has sustained suppression of northern pike in the middle Green River (Monroe and Hedrick 2008). The appearance of increased numbers of northern pike in the Thunder Ranch backwater of the Green River and in the upper Colorado River in 2011 and 2012 contributed to consideration of developing a rapid-response crew which could respond in on-call fashion to assess the potential for invasion by new or familiar invasive species appearing in new location in the UCRB. This concept, including the need to identify/establish a crew, funding, and an equipment cache to implement a rapid-response, was discussed by the Nonnative Fish Subcommittee in 2012 and was recommended as "**high priority**" (***NNF1012***).

Hazard Analysis and Critical Control Point (HACCP)

Given the prime importance of prevention as the best defense against mounting problems with nonnative aquatic species and their invasive impacts in the UCRB, the use of HACCP protocols is recommended for all importations of aquatic species from outside the UCRB and for any transfers of aquatic species within the UCRB. This recommendation applies to movements of both nonnative and native aquatic species by the public, commercial and private sectors due to the increasing risk of invasive species being introduced as aquatic hitchhikers in holding water. The case of gizzard shad *Dorsoma cepedianum* introduction into the UCRB by inadvertent inclusion in a load of largemouth bass *Micropterus salmoides* stocked in a reservoir in the San Juan River basin in New Mexico is emblematic of the risk of aquatic hitchhikers and the need for HACCP training and protocols in aquaculture operations and fishery management activities (USFWS-NCTC 2004). Appendix C provides additional detail and documentation of the extensive spread of gizzard shad in the UCRB, including a discussion of the potential ecological complications this species poses for sport fisheries and native aquatic communities in the UCRB.

HACCP provides a step-by-step analysis of individual procedures involved in aquaculture operations or fishery management activities to help identify vulnerabilities for contamination by unwanted species and their inadvertent transport. This analysis process pinpoints opportunities for closing pathways that could inadvertently introduce unwanted species. Strict application of HACCP protocols helps identify best management practices that can be implemented and updated to prevent invasive species transport or introductions. Best management practices are only effective if implemented and failure to do so may result in adverse ecological impacts or future restrictions for aquaculture/management activities. HACCP has been incorporated into many aquaculture activities of state and federal agencies in the UCRB, but it remains unclear if HACCP training or its application has been undertaken in private sector aquaculture operations or agency field activities. Ensuring the availability of HACCP training and its application in private aquaculture operations and fishery agency field operations is recommended as a "**high priority**" (***NNF1012***). Appendix D provides an example of the HACCP protocol applied by Wyoming Game & Fish for the transplant of roundtail chub *Gila robusta* from the Halfmoon Lakes into Scab Lake in 2009.

The Upper Basin Fish Chiefs recognized that agency jurisdiction is an issue with regard to applying HACCP in the private sector. In Colorado and Utah the Department of Agriculture would have enforcement authority, not the wildlife agency. And they suggested that promotion of this method of prevention should also consider making "HAACP certification" a bonus, a positive that makes private vendors more marketable. Example - Arkansas bait fish industry, where vendors can market themselves as "certified" that customers will get the species they requested.

II. <u>Eradication, Control, and Management</u>

Eradication should be the goal of invasive species management since it removes the need for further control and ongoing environmental or economic costs. Eradication is best applied when problematic species first appear and their numbers are low and not widespread. Otherwise, species invasions are often irreversible and many species, once established, may prove difficult or impossible to eradicate without excessive collateral damage to native species (Myers et al. 2000; Cucherousset and Olden 2011). This predicament clearly reiterates the importance of prevention as the cornerstone of nonnative and invasive species management (Vander Zanden and Olden 2008). However, due to the inability of the most diligent and effective prevention strategies to eliminate introductions of nonnative species or their invasive impacts (Vander Zanden et al. 2010), 1) methods of early detection, eradication or continuing control must be applied (Gherardi et al. 2011) and 2) native species conservation will involve management of mixed assemblages of native and nonnative species (Cucherousset and Olden 2011).

Integrated Pest Management

Definitions of Integrated Pest Management (IPM) vary to both include prevention as a foremost strategy (EPA 2011) or exclude it in favor of maintaining pests at the maximum level just below the economic threshold (e.g., the lowest population level that will cause economic damage) to contain control costs. A combination of such definitions is used here to apply IPM in the UCRB for the control of problematic species using a collection of techniques that target specific biological attributes in an economically, socially and ecologically viable manner that is sustainable over the long-term. Clearly, prevention must be applied vigorously to avoid additional ecological or economic costs for nonnative aquatic species control in the UCRB. Next, utilizing all available techniques, optimizing their application, and evaluating their effectiveness will be required to more efficiently combat invasive species and their impacts in the UCRB. These actions may include eradication attempts in specific waters or well-defined spatial areas, population control by suppression through removal programs and/or containment of existing populations to prevent their further spread (Britton et al. 2011). Enlisting the support and assistance of other agencies to implement an IPM approach was ranked as "**high priority**" (***NNF0209***). An example of this multi-agency assistance would be the administration of a bounty for a problematic nonnative species by agencies with offices or facilities close to the habitat area targeted for control.

Electrofishing

Electrofishing is performed in UCRB rivers within critical habitat or in adjacent upstream reaches or tributaries to sample native fishes or remove nonnative fishes. Typically, electrofishing at lower elevations in the rivers of the UCRB captures of a wide variety of warmwater species including cyprinids, catostomids, esocids, ictalurids, centrarchids, and percids, but comparatively few salmonids. Electrofishing has become the primary means to attempt reduction and control of nonnative fish populations in the UCRB. In some cases, multiple passes in some river reaches are required to conduct mark-recapture population estimates, with additional passes being required to meet projections for depletion of target nonnative fishes based on capture probabilities (Haines and Modde 2007; Breton et al. 2013).

The CRRP and San Juan River Recovery Programs use electrofishing boats or rafts to capture fish in several hundred miles of river annually at ambient water conductivities ranging from 100 to 1,500 µS/cm. Boats provide increased mobility in larger rivers during high flows when water conductivities are typically lower and rafts are used on smaller rivers or during low flow periods when water conductivities may be higher. The electrofishing fleet of the recovery programs currently consists of seventeen water craft representing a combination of 4.9-5.5 m long aluminum-hulled jon-boats and 4.3-4.9 m long whitewater rafts or catarafts. An electric seine is also used to collect primarily small bodied fishes (Bestgen et al. 2007b).

Standardization of the electrofishing fleet has been undertaken to optimize electrofishing effectiveness and minimize injury to fish (Miranda 2005; Martinez and Kolz 2009). Four models of electrofishers were evaluated for their capacity to sustain power output in both electrofishing boats and rafts to further promote standardization of the Recovery Program's electrofishing fleet across the range of water conductivities encountered (Martinez and Kolz 2013). Exploring the use of alternate brands or models of boat-electrofishers was ranked as "**high priority**" (*NNF0209*). Standardization of electrofishing operations requires the use of electrodes of similar configuration, spacing and electrical resistance. Standardizing the electrical waveform and power output requires the use of appropriate electrofisher control settings to maintain a constant transfer of electrofishing power across the range of water conductivities encountered is recommended as a "**high priority**" (***NNF1012***). Identifying fish response thresholds specific to the standardized electrofishing boat and rafts, and the boat-electrofisher used with the craft (Appendix F), to refine electrofisher settings is also recommended as a "**high priority**" (Martinez and Kolz 2013; ***NNF1012***). Appendix F provides Standard Operating Procedure (SOP) guidelines for the Recovery Program's electrofishing operations.

Pesticides

Pesticides offer the potential for local eradication when properly applied under favorable conditions. While piscicides for the eradication or control of fish are readily available and widely applied, particularly rotenone (Finlayson et al. 2010), they remain indiscriminate, often being toxic to nearly all fish species and some invertebrate taxa, dependent in part on the water conditions and concentration of the active ingredient at the time of application. As a consequence, non-target species may be killed in situations where the need to eradicate or reduce the abundance of invasive species arises. Similarly, no pesticides are known to be selective for crayfish resulting in chemical treatments for crayfish in small bodies of water that are readily available, comparatively inexpensive, and do not persist in the environment, such as rotenone, BETAMAX VET (synthetic pyrethroid) and ammonium (Gherardi et al. 2011). Martinez (2004) applied piscicides in floodplain ponds along the Colorado and Gunnison rivers in Colorado in an attempt to control chronic sources of nonnative fishes, including nonnative centrarchids (particularly largemouth bass), entering critical habitat. While reinvasion of ponds was evident, and in some cases rapid, it appeared that largemouth bass did not reinvade as readily as other species (Martinez 2004), but there was no evidence of an associated, persistent reduction of nonnative fish density in backwaters (Martinez and Nibbelink 2004). Rotenone was successfully applied in the Old Charlie Wash wetland adjacent to the Green River in Utah to remove northern pike (Monroe et al. 2008). Small-scale spot treatments using piscicides to eradicate nonnative fish in isolated habitats was ranked as "**high priority**" (*NNF0209*).

Large scale application of pesticides to eliminate invasive threats or impacts by nonnative aquatic species in reservoirs or rivers has been discussed, but no projects have been implemented to date. The need for large scale application of pesticides will increase as problematic species increase in distribution and abundance through illegal introductions and emigration into critical habitat. Piscicide treatments in larger reservoirs are undertaken occasionally, typically to improve conditions for sport fish. Treatments to remove problematic species that may increase or perpetuate the risk or occurrence of invasive impacts in critical habitat had not been performed in the UCRB until 2012 when Paonia reservoir was treated rotenone to remove its population of northern pike. Large scale applications of piscicide have not been used in large rivers in the UCRB to reduce the abundance of problematic nonnative fishes for the benefit of the native aquatic community. While large-scale application of piscicides was recommended for further consideration and implementation, it was ranked as "**low priority**" due to its high cost and uncertain outcome (***NNF0209***). However, more recently, prioritization of waters (primarily reservoirs) was recommended as a "**high priority**" to expedite assessment of the feasibility and cost associated with treating individual water, and to expedite this management option (***NNF1012***). In 2012, Colorado Parks and Wildlife treated Paonia Reservoir (target species – northern pike) in the Gunnison River drainage and Miramonte Reservoir (target species - smallmouth bass; Dolores River drainage) in 2013. Utah Division of Wildlife has also committed to treating Red Fleet Reservoir (traget species - walleye, Green River drainage) in 2014.

Nets

Various types of nets have been used in the UCRB as part of nonnative aquatic species sampling and removal efforts. Gill nets, trammel nets, and trap nets continue to be used for the capture of nonnative fishes in both lotic and lentic habitats. Lift nets and baited traps have been used to capture crayfish. Consideration must be given to mesh aperture, duration of sets, or risk of unauthorized retrieval if by-catch mortality of non-target species is of concern. Nets may be selective for certain species or sizes of fish depending on seasonal or environmental factors, but they remain largely indiscriminate, passively entangling or capturing fishes in the vicinity. The potential loss of low numbers of native fishes may have to be weighed against projected or potential losses to predation by nonnative piscivores in determining the intensity of net use. The judicious use of nets is recommended to maximize the removal of target nonnative aquatic species. The use of multiple gear types was ranked as "**high priority**" (*NNF0209*).

Escapement screens

The Stocking Procedures (USFWS 2009) require the use of screens to control the escapement of stocked, nonsalmonid fishes from ponds and reservoirs. Three functional categories of screens/barriers have been applied in the UCRB to aid control of nonnative, nonsalmonid fishes. These include installation of screens on outlets of reservoirs or in stream channels to control escapement, entrainment, or downstream movement by nonnative fishes from these sources. Irving and Montoya (2002) and Martinez (2004) provides examples of screens adaptable for use on small ponds releasing low flows from their outlets. Second, natural features or constructed barriers (screens) can serve to limit fish movement into rivers, canals or ponds. Last, an effort to limit downstream movement of piscivores from their area of greatest reproduction, recruitment or abundance has been attempted by their selective removal within a "buffer" between their upstream source area and critical habitat for endangered fishes below the buffer. Assumptions about the effectiveness of nets, screens, buffers or strategies intended to limit or prevent fish escapement or movement into Critical Habitat should be avoided without a preliminary assessment, including outside peer-review of the screen's location and design, or ongoing monitoring of their effectiveness and a reevaluation of their function and suitability for controlling the movement of problematic fishes if escapement is documented. Equally important is the capacity and commitment to sustain the operation and function of these structures or strategies in perpetuity, in lieu of eradication or sufficient suppression of the source population of problematic species.

An example of a reservoir screen is the spillway net at Highline Lake in west-central Colorado, which is fabricated of the high tech fiber Dyneema, a high molecular weight polyethylene material. This material was well suited for the net at Highline due to its resistance to abrasion, light degradation, and fatigue without special coverings or coatings (Martinez 2002). The net is 363 feet wide, 19 feet deep, has a dry weight of 1,400 pounds and mesh openings of 0.25 inches (Martinez 2001). The first net had a projected service life of up 5 years under local conditions (Martinez 2000) and was in place six and a half years, until March 2006. It was determined that the net could be left in place year-round, even during winter when the lake is frozen (Martinez 2001). The net that was initially installed in 1999 was replaced with an identical net in 2006. A dive team has been used to clean algal/debris buildup from the net two to three times per year (Martinez 2002).

In addition to the year-round monitoring and maintenance of the net by State Parks personnel, the Colorado Division of Wildlife (CDOW) performed an evaluation of fish escapement following the net's installation. Evaluation of the net's performance in controlling escapement of resident and stocked nonnative fishes from the reservoir was favorable (Martinez 2002). The Recovery Program has recommended maintaining a net at this site to continue to control escapement of nonnative fish (PDO 2002). The stocking of warm-water fish species was allowed under the Stocking Procedures (USFWS 1996) due to the placement of the net at Highline Lake has proven popular with anglers. The effectiveness of outlet screens is dependent on their monitoring and maintenance to ensure their function. Implementing alternate strategies to best prevent nonnative fish escapement from unscreened outlets, such as releasing water during periods of hypolimnetic oxygen depletion to prevent or minimize fish entrainment/escapement, is recommended.

Mandatory annual maintenance/opening of the Highline Lake outlet, which would be an unscreened release of water from the reservoir, is recommended to be performed during the summertime period of hypolimnetic oxygen depletion to prevent/minimize entrainment or escapement of warmwater fish species. Piper et al. (1982) reported that fish thrive at $\geq$ 5 mg/l of oxygen, show a decrease in feeding and growth from 3-5 mg/l, and may die from 0-3 mg/l, depending on the species. The EPA (1986) provides information showing that various life stages of several species of nonnative warmwater fish known to occur in Highline Lake are tolerant of oxygen levels < 5 mg/l, including smallmouth bass *Micropterus dolomieu* (Edwards et al. 1983) whose escapement from the reservoir is of particular concern. Burdick et al. (1954) reported that lethal oxygen concentrations for smallmouth bass ranged from 0.73-1.15 mg/l at 60-80^{o} F. Martinez (2002, 2003) reported that oxygen levels typically fell below 2/mg/l below a depth of 6-8 from mid-July until late August and recommended this 2 mg/l threshold for future unscreened outlet releases. Given annual variation, monitoring oxygen levels near the outlet in Highline Lake to detect the period when oxygen is > 2 mg/l should provide up to a six-week window between the first week of July and the first week of September in which the mandatory annual maintenance/opening of the Highline Lake outlet could be performed. In 2013, CPW developed a sock net attachment for the outlet works, which could be deployed during future annual outlet tests.

In contrast, Elkhead Reservoir in northwest Colorado was equipped with outlet screens, but not a spillway screen. Elkhead Reservoir was recently enlarged to improve water storage capabilities in the Yampa River Basin and to supply water for supplementing the depleted base flows of the Yampa River to benefit endangered fish in Critical Habitat (Roehm 2004). As part of the reservoir's enlargement, multiple screening devices were installed in the outlet tower to control fish escapement. Monitoring of recaptured, tagged bass revealed excessive escapement of resident and translocated smallmouth bass from Elkhead Reservoir, attributed in part a greater magnitude and frequency of spills from the reservoir following reconstruction (Breton et al. 2012). Due to the impracticality of net/screen in the spillway or at a downstream location to control fish escapement, the translocation of smallmouth bass from the Yampa River into Elkhead Reservoir was suspended in 2011 (CRRP 2011a). Breton et al. (2012) further stated that escapement rates of smallmouth bass from Elkhead Reservoir would render smallmouth bass removal efforts in the Yampa River ineffective in a short time.

A third screen design has been used at Juniata Reservoir in the Gunnison River drainage and at Rifle Gap Reservoir, near the town of Rifle, Colorado. These screens were constructed in the tributary below the dam, controlling the downstream movement of fish escaping or entrained in releases from either the spillway or outlet (USBR 2011a). The Rifle Gap screen's location and design underwent peer-review by non-CRRP personnel with regional expertise and monitoring for fish escapement past the screen and ongoing maintenance were stressed to evaluate and ensure the screen's function (USFWS 2011a). Due to the presence of a suite of nonnative predatory species, including northern pike, smallmouth bass, and walleye in the reservoir, the U. S. Fish and Wildlife Service recommended a five year monitoring period to evaluate the screen's effectiveness in preventing the downstream movement of fishes(USFWS 2011a). Specimens of each of these predatory species captured in the Colorado River within critical habitat have been suspected (smallmouth bass, McAda and Burdick 2005) or confirmed (northern pike, Johnson et al. 2013; walleye, Wolff et al. 2012) to have originated from Rifle Gap Reservoir.

While additional screens may be installed to control escapement of nonnative fishes from reservoirs or ponds in the UCRB, it must be understood that maintenance of screens and their infrastructure is an ongoing, necessary, and expensive commitment. Screens may facilitate stocking or maintenance of high densities of predatory sport fishes in reservoirs for angling recreation, which may contribute to the escapement of sufficient numbers of a particular species exceeding its propagule size and capable of triggering an invasion if the screen fails periodically or for an extended period. It is recommended as a "**high priority**" (***NNF 0209, NNF1012***) that screens be used to manage sport fish populations based on Compatible list species that are considered to be compatible with endangered fish recovery and not for management of Non-compatible list or demonstrably invasive species in the UCRB, including northern pike and smallmouth bass. Monitoring of all screens on public waters and reporting on their function and maintenance on an annual basis is recommended as a “**high priority**” to help ensure their reliability in preventing/controlling fish escapement (***NNF1012***).

Exclusion barriers

Exclusion barriers of varying scale have been applied, exist, or have been proposed in a variety of habitats. Martinez (2004) installed wedge-wire screens to prevent invasion of ponds, but found that some larval nonnative fishes were able to pass through 0.5 mm openings. Hill (2004) evaluated the potential placement of barrier screens in the mouths of backwaters in the upper Yampa River to prevent northern pike access spawning habitats. Small aperture screens (1/4 inch) placed in the mouths of backwater in the Green River suggests that this treatment excludes nonnative predators, primarily centrarchids, and may increase the numbers of young-of-year native fishes (Hedrick et al. 2010). Larger scale examples of exclusion barriers exist at the selective fish passage structures on the Gunnison and Colorado rivers near Grand Junction, Colorado. These fish ladders are operated seasonally and before individual fish can pass upstream, they are manually sorted to remove nonnative species. While highly effective at preventing the upstream movement of nonnative fishes, the upstream river reaches they protect are vulnerable to escapement from reservoirs or illegal introductions of problematic species in upstream habitats (Johnson et al. 2009). A natural barrier (waterfall) at the mouth of the San Juan River where it empties into Lake Powell (USBR 2011b) created by the reservoir’s drawdown, prevents the upstream movement of nonnative fishes from the reservoir into riverine critical habitat. A potential strategy for creating similar barrier scenarios would be the use of a floating weir in a select river reach or tributary mouth to exclude nonnative fishes (Monroe et al. 2009; Tobin 1994; Stewart 2002, 2003). Exclusion barriers have potential to benefit recovery and preservation of native fishes and their further evaluation is a “**high priority**” as it may be among the few methods to locally manage the negative impacts of nonnative small-bodied fishes in native fish nursery habitats (***NNF1012***). The use of large passive weirs in a multi-gear approach to control/exclude nonnative fishes was ranked as “**high priority**” although it was acknowledged that this concept required further investigation (***NNF0209***).

Downstream buffers

Efforts to remove northern pike from Lake Catamount, situated in the upper Yampa River basin, and from the Yampa River between Hayden and Craig provide examples of buffers between source areas of northern pike, and suitable habitats downstream. The buffer concept proposes to intercept northern pike within the buffer area in an attempt to reduce their abundance and predation within the buffer and in habitats downstream. Lake Catamount is known to contribute northern pike downstream into the Yampa River, including in critical habitat (Orabutt 2006; Finney and Haines 2008; Martin and Wright 2010). Intensive removal of northern pike from Lake Catamount using trap nets, electrofishing, and angling have reduced the numbers of northern pike (B. Atkinson, Colorado Division of Parks and Wildlife (CPW), unpublished data), but pike can reinvade the reservoir from Stagecoach Reservoir upstream (Rogers et al. 2005) where pike had been introduced illegally. The highly suitable habitat for northern pike in Lake Catamount (extensive littoral and vegetated areas; Fitzpatrick and Winkelman 2009) represents a "pike-replicator" scenario in which the species would be expected to rapidly repopulate without a dedicated level of ongoing removal to sustain suppression of the population or eradicate them from original source upstream in Stagecoach Reservoir.

Northern pike in the upper Yampa River near Steamboat Springs are believed to originate from the numerous ponds in the floodplain that connect to the river (Hill 2004), and from Catamount Reservoir (Fitzpatrick and Winkelman 2009). In 2004 and 2005, the density of northern pike (≥300 mm TL) in 28 miles of this reach averaged 28.3/mile (Finney and Atkinson 2005). Many of the northern pike in the Yampa River buffer between Hayden and Craig (the upper limit of critical habitat) originate from upstream sources, as indicated by movement of tagged pike (Finney and Haines 2008). Northern pike tagged within the buffer and upstream in the Yampa River move downstream into critical habitat in the Yampa and Green rivers (Finney and Haines 2008; Monroe and Hedrick 2008; Martin and Wright 2010), a pattern exacerbated by the high densities of northern pike in these upstream reaches. The average density of northern pike (≥ 300 mm TL) in the buffer (38 miles) from 2004-2010 was 30.8/mile (Finney and Haines 2008; Webber 2008, 2009, 2010). Both annual densities (18.4 - 46.6/mile) and the average density of northern pike in the buffer remained higher than in the middle Yampa River (76 miles) during the same time period which ranged from 8.2 -14.1/mile and averaged 10.2/mile for pike > 300 mm TL (Wright 2010). Identifying and remedying channel modification in Yampa River (elsewhere if appropriate) to advantage native fish reproduction and recruitment and to disadvantage nonnatives, primarily northern pike, is recommended as a "**high priority**" (***NNF0209***).

Relying on the "buffer approach" as the primary means of controlling the downstream invasion by northern pike into critical habitat is not a sustainable, long-term approach to promote recovery of Colorado pikeminnow in the Yampa River or within the UCRB. The average density of northern pike in the Yampa River above critical habitat, ~30/mile, is over 10 times that of the reduced pike density, 2.67/mile, targeted by interim criteria in the YAR Strategy (Valdez et al. 2008). A more recent criterion recommends that the density of northern pike not exceed that of Colorado pikeminnow in critical habitat, which is presently depressed at 1.9/mile (Bestgen et al. 2010); thus northern pike remain about five times more abundant than Colorado pikeminnow within critical habitat. The current strategy of selectively removing northern pike only in certain habitats has failed to adequately suppress the density of northern pike in critical habitat. The release of tagged pike in the buffer was ceased in 2011 to increase the number of pike removed annually (CRRP 2011a). To more effectively reduce pike abundance in the Yampa River, a more comprehensive approach, targeting adults in the mainstem river and in source habitats used for reproduction will require increased use of currently applied techniques (electrofishing, trap nets, barriers, angling), incorporation of under-utilized techniques (must-kill regulations, harvest incentives, piscicides) and experimentation with new techniques (e.g., sound cannons in spawning concentration areas). This approach implies and conveys that maintaining northern pike in upstream reach with a direct connection to critical habitat is compatible with endangered fish recovery. Replacing this strategy with one more focused on eradication of northern pike in the rivers and connected habitats in the UCRB is recommended as a "**high priority**" (***NNF1012***).

Mandatory harvest and monetary incentives

The removal of bag and possession limits for nonsalmonid sport fish within critical habitat in the UCRB was intended to promote the harvest of these fishes, reduce their populations within riverine habitats, and to convey the management priority given to native fishes in these rivers. More recently, the removal of bag and possession limits for nonsalmonid sport fishes has been expanded in Colorado to include river reaches above critical habitat and larger tributaries flowing into critical habitat. In Utah, regulations have been adopted requiring anglers to kill any smallmouth bass or burbot they catch in the Green River. Despite expansion of these liberalized harvest regulations for problematic piscivores, it is uncertain whether anglers are presently contributing meaningfully to the reduction of these species. In Utah, the densities of the species subject to the must-kill regulation are comparatively low, so the regulation may be preemptive. In Colorado, where densities of the target species are high, an effort is underway to normalize the message amongst various agencies to promote sport fishing that is compatible with native species conservation within critical habitat and in adjacent reaches or connecting habitats. A more coordinated message and consistent application of must-kill regulations for invasive predatory fishes is recommended as a "**high priority**" (***NNF0209, NNF1012***). The policy and practice of translocating problematic predatory species removed from rivers represents a direct contrast and conflict regarding the invasive threat these species have demonstrated and pose for endangered fish recovery. Rather than convey or support the need to eradicate these species in rivers riches or adjoining habitats enjoining or adjacent to rivers supporting endangered fishes, the species continue to be stocked and promoted. It is recommended as a "**high priority**" (***NNF1012***) that of problematic species removed from UCRB rivers no longer be translocated to any habitats within the UCRB.

Incentives that entice angler to pursue target species and reward them for removing and killing problematic fishes may facilitate the effectiveness of regulations intended to contribute to the reduction and control of target problematic species. Presently, a harvest incentive is only applied in one location in the UCRB, in Wolford Mountain Reservoir near Kremmling, Colorado for illegally introduced northern pike (Ewert 2010). A $20 reward for each pike killed by anglers is paid by the Colorado River Water Conservation District (CRWCD 2011). In addition to concerns about predation by northern pike on stocked salmonids (CRWCD 2011), the reservoir contains a population of native roundtail chub (Ewert 2010). Bounties ranging from $10-$15 for predatory salmonids in Lake Pend Oreille (Martinez et al. 2009) accounted for half of the 100,000+ lake trout *Salvelinus namaycush* removed from the lake (CBB 2010). A similar reward program is recommended as a "**high priority**" (***NNF1012***) (e.g., Yampa River northern pike, White River smallmouth bass, etc.) to better incorporate the concepts of Integrated

Pest Management and the application of multiple gear types, two strategies that rate as "**high priority**" (***NNF0209***). Zipkin et al. (2009) examined life history characteristics of various nuisance and invasive species and categorized northern pike as a species that would not display overcompensation in response to intensive harvest. Unfortunately, the same researchers reported that a seven-year removal effort for smallmouth bass population in a northern temperate lake resulted in a larger population size. This demonstrates the need to develop Integrated Pest Management approaches that are species and site-specific.

III. Research and Monitoring

Research to better understand the food web interrelationships of native and nonnative aquatic species would help to prioritize the most problematic species for eradication or control using available techniques, or reveal the need for research to develop the appropriate strategies and tools for species for which control techniques are not readily available. For all nonnative aquatic species subject to control, identifying target levels of population suppression will be required to evaluate progress toward achieving removal goals. To achieve and sustain management goals for nonnative aquatic species and their presently occurring or threat of invasive impacts, research to identify and implement additional or new equipment, techniques, or strategies, needed to prevent, eradicate or control problematic populations is warranted. Recommendations for this section and a timeline for implementation are provided in Table 3.

Propagule pressure

Propagule pressure is a combination of the number of discrete release events (propagule number) and the number of individuals release in a single event (propagule size; Lockwood et al. 2005). Functionally, propagule pressure is single or multiple additions of nonnative species from individual or multiple sources or pathways that contribute eggs, larvae, juveniles or adults capable of creating a reproducing propagule that establishes a self-sustaining, potentially invasive population. Establishment of nonnative species which may become invasive is correlated with the frequency of introduction events and the number of individuals introduced = propagule pressure (Colautti et al. 2006). Simberloff (2009) concluded that increasing propagule size enhances establishment probability primarily by lessening effects of demographic stochasticity, whereas propagule number acts primarily by diminishing impacts of environmental stochasticity. A continuing rain of propagules, particularly from a variety of sources, may erase or vitiate the expected genetic bottleneck for invasions initiated by few individuals (as most are), thereby enhancing likelihood of survival. Therefore the Recovery Program should focus control / containment efforts on chronic sources of escapement.

Species that have been purposefully, accidentally, or illegally introduced may become invasive, threatening the prospects of perpetuating native aquatic communities in the UCRB upon which the recovery of endangered fishes depends. For example, Franssen et al. (2007) demonstrated the preference for available native prey fish by endangered Colorado pikeminnow, despite the numerical dominance and availability of nonnative fish prey.

Information in Appendix G illustrates that single introduction events in reservoirs can establish populations of nonnative fish that have or may escape into UCRB rivers. Further, this information suggests that very low propagule densities in rivers have the potential to establish populations of nonnative predatory fishes that may become invasive, hampering the recovery of endangered fishes. Interim targets for reductions of smallmouth bass (30 smallmouth bass >200 mmTL/mile) and northern pike (3/mile) within critical habitat in the Yampa River (Valdez et al. 2008) may allow a rapid resurgence of these species. Thus, these targets should not be adopted for other rivers in the UCRB and should likely be lowered for the Yampa River in accordance with the risk of population establishment or resurgence associated with the propagule densities discussed in Appendix Table G-2. Mueller (2005) recommended convening a panel of experts to assist in developing strategies to combat predation on native fishes, including reducing and maintaining densities of unwanted communities by 80%. Examination of the interim reduction criteria for northern pike and smallmouth bass the Yampa River (Valdez at al. 2008) is recommended as a "**high priority**" (***NNF1012***) using propagule size. Basing target removal densities on an aerial rather than river-mile basis may better identify an ecologically-based target density suited to the long-term suppression of invasive piscivores.

The low propagule densities identified in Appendix Table G-2 also illustrate the need to better prevent access by nonnative predatory fishes into critical habitat from upstream river reaches, tributaries, ponds, and reservoirs, or via illegal stocking. Allowing an ongoing influx of new or existing species into critical habitat undermines removal efforts and reduces the prospects of sustaining suppression of problematic species. Introductions of inadequate size or frequency will result in establishment failure = reduced propagule pressure and reduced invasion risk (Drake and Lodge 2006). Applying the concepts of propagule size (Duggan et al. 2006; Reaser et al. 2008) or Allee thresholds (Keitt et al. 2001; Drake and Lodge 2006) may provide a better understanding for projecting and evaluating critical population densities below which target invasive species cannot persist.

Population modeling

Evaluation of available population data for smallmouth bass (Haines and Modde 2007; Winkelman et al. 2011) and northern pike (Bestgen et al. 2011) in the UCRB will evaluate the status of these populations in critical habitat, identify their population trends in response to removal efforts, and provide a basis for adjusting the amount of control effort required to achieve reduced levels of abundance for these invasive species (Bestgen et al. 2011; Breton et al. 2013). Further, population modeling for smallmouth bass has helped identify and verify problematic river reaches for this invasive species in the UCRB and may facilitate allocation of removal effort to increase the likelihood of achieving and sustaining its suppression (Breton et al. 2013). In analogous removal efforts for lake trout in large lakes in the western U. S., population modeling has been used to assess prospects for successful suppression, the effectiveness of suppression efforts and to prescribe the level of removal effort required to collapse invasive lake trout populations to target levels (Hansen et al. 2008; Dux et al 2011; Syslo 2010; Syslo et al. 2011). For population eradication/suppression to be successful the number of individuals produced in a population must be exceeded by the number removed (Bomford and O'Brien 1995; Syslo et al. 2011).

Understanding population metrics, and movement and distribution patterns, are key to implementing successful suppression programs and avoiding reactionary, quick actions that may result in a less effective approach to suppression (Dux et al. 2011). Research to better understand abundance and population dynamics of northern pike in the UCRB is being conducted by Bestgen et al. (2011). This research is expected to evaluate the effect of pike removal in the buffer area on pike populations in downstream critical habitat, aid assessment of immigration from sources upstream, explore the influence of important environmental factors on northern pike abundance, and project trajectories of pike populations under different levels of removal effort. However, rapid detection and an expedient suppression response remain advisable to increase the effectiveness of eradication efforts (Simberloff 2003; Syslo et al. 2011). Given the negative impact to native and endangered fish attributed to northern pike in critical habitat in the Yampa River, it is recommended as a "**high priority**" (***NNF1012***) that control of this invasive predator should proceed in an aggressive manner, incorporating refinements as more is learned from control and modeling efforts.

Sources of nonnative fishes

Evaluation of nonnative fish escapement from reservoirs has been conducted at several UCRB reservoirs including Highline (Martinez 2001, 2002) and Elkhead reservoirs (Miller at al. 2005; Breton et al. 2013) in Colorado, and Starvation Reservoir in Utah (Brunson et al. 2007). The recapture of tagged fishes in escapement studies facilitates estimation of escapement rates and distance moved following escapement. However, conducting studies of tagged fishes at all potential sources of problematic species would likely be impractical due to the commitment of time and funds necessary to capture, tag and recapture the tagged specimens. The Recovery Program has funded or related research has demonstrated the utility of microchemical analyses of naturally occurring stable isotopes and elemental signatures of water and otoliths for identifying sources of fishes at both fine- and large-scales in the UCRB (Martinez et al. 2001; Whitledge et al. 2006; Whitledge et al 2007; Fitzpatrick and Winkelman 2009; Wolff et al. 2012). Assessing the risk of nonnative, nonsalmonid fish escapement from reservoirs in the UCRB, including the use of microchemical techniques, is a recommended strategy (*NNF0209*). The need to identify origins of nonnative, nonsalmonid fish species already present in the UCRB in new locations or at higher densities in critical habitat and the appearance of new fish species will continue to arise in the future. Microchemical analyses also offer potential as a forensic tool for tracking illegal stocking of fishes (Johnson et al. 2007; Gibson-Reinemer et al. 2009).

Identifying origins and incidence of nonnative nonsalmonid fishes in critical habitat that have escaped from ponds or reservoirs can contribute to identifying the most problematic sources of these species and prioritizing locations where actions are needed to prevent escapement of nonnative fish (***NNF0209***). Application of this technique in the UCRB has become a "**high priority**" (***NNF0209, NNF1012***). Additional research is recommended as a "**medium priority**" to refine the capabilities of this microchemical technique for water with similar signatures (***NNF1012***). Just as DNA evidence is useless without a suspect, otoliths obtained from fish suspected of escaping from a pond or reservoir must be compared to suspected sources. Chemical signatures of many sources in the UCRB have already been documented but in some cases it may be necessary to collect additional reference samples from a capture location and possible source locations. Species effects on signatures are insignificant for all but walleye and some additional work to examine mechanisms for that difference is needed (***NNF1012***). More research is also recommended as a "**medium priority**" to evaluate differences in river vs. reservoir signatures near dams (***NNF1012***).

Streamflow trend and reservoir release effects on nonnative fishes

High spring discharge is often beneficial to native fishes in the Colorado River basin (Osmundson and Burnham 1999; Paukert and Rogers 2004; Gido and Propst 2012), however, negative impacts to nonnative fishes due to flow induced environmental effects may be difficult to discern (Coggins et al. 2011). Low stream flows in the UCRB appear to favor species such smallmouth bass and virile crayfish which benefit from earlier reproduction and longer growing seasons due to warmer water temperatures (Martinez 2012). Northern pike and largemouth bass abundance in UCRB rivers appears to increase following high water events which may be due to the earlier and extended connection of floodplain habitats, possibly facilitating reproduction or access to the river from habitats that were formerly disconnected from the mainstem (Whitledge et al. 2007). Gaining a better understanding of the influence of discharge on water temperature and habitat inundation or connection in relation to reproduction, recruitment, growth, dispersal, and abundance of nonnative fishes is recommended as a "**high priority**" (***NNF0209, NNF1012***). In addition to the potential ecological implication of flow events or manipulations, prolonged periods of sustained flows may facilitate removal of nonnative fishes. Examining the utility of flow releases from Elkhead Reservoir to prolong access to key habitats for extended summertime removal of nonnative fishes vs. reserving releases to supplement base flows is recommended as a "**medium priority**" (***NNF0209, NNF1012***).

Experimental manipulation of reservoir releases to disadvantage nonnative fishes or prolong mechanical removal of problematic nonnative species may become more complex if the flow adjustments negatively affect native fishes or enhance the success of other nonnative fishes (Brown and Ford 2002; Craven et al. 2010). Smallmouth bass and white sucker appear to be recent invaders in the Lodore Canyon reach of the Green River, Colorado, within Dinosaur National Monument (Bestgen et al. 2007c). River flows and water temperatures in Lodore Canyon can be influenced by releases from Flaming Gorge Dam in Utah and may provide a means to disadvantage reproduction by smallmouth bass.

Smallmouth bass begin to spawn when water temperatures reach 15°C (Lukas and Orth 1995), but white suckers typically do not spawn in water temperatures exceeding 15°C (Hamel et al. 1997). Bestgen et al. (2007c) reported that white suckers in Lodore Canyon declined from upstream to downstream, a pattern expected for a species that is more common in cooler upstream reaches than in warmer waters downstream. Increases in flows and a reduction in water temperatures that may disadvantage smallmouth bass may prove advantageous for white sucker (Bestgen et al. 2007c) or northern pike. Increases in the distribution of nonnative fishes in the UCRB, or the addition of new species, may complicate or eliminate some management options that might have been used to control specific invasive species or life stages if the control strategy results in collateral impacts by other invasive species.

Investigating the availability and utility of reservoir releases to alter hydrographs, and potentially thermographs and sediment transport (turbidity), to disadvantage spawning and nesting behaviors and success of smallmouth bass ranked as "**high priority**" (***NNF0209, NNF1012***). Smallmouth bass spawning success in lotic habitats may be negatively affected by acute reductions in water level which can cause nest abandonment (Montgomery et al. 1980). Conversely, high flows can be associated with year-class failures (Smith et al. 2005), which may sweep eggs or fry from nursery areas (Mason et al. 1991). Smallmouth bass spawning and recruitment is often favored by lower flows and associated warmer water temperatures (Graham and Orth 1986, Swenson et al. 2002), thus higher flows coupled with lower water temperatures may prove detrimental to smallmouth bass reproduction. Smallmouth bass may also be susceptible to increased turbidity or siltation which can disrupt spawning or feeding (Berkman and Rabeni 1987; Sweka and Hartman 2003). Better understanding of these mechanisms by examining daily otolith increments can provide the dates of spawning, thereby facilitating the focus of removal effort during times when spawning, nesting, or hatching might be interrupted to reduce recruitment of problematic species. Analysis of young-of-year (YOY) smallmouth bass otoliths to better understand their spawning chronology in relation to flow events or manipulations is recommended as a "**high priority**" (***NNF1012***). Evaluating the utility of this technique for similarly understanding the timing of spawning in other species (e.g., YOY largemouth bass, northern pike and walleye) as an aid in targeting removal or reducing recruitment during the period or at the location of their spawning is recommended as a "**medium priority**" (***NNF1012***).

Potential effects of climate change

The terms "climate" and "climate change" are defined by the Intergovernmental Panel on Climate Change (IPCC 2007). "Climate" refers to the mean and variability of different types of weather conditions over time, with 30 years being a typical period for such measurements, although shorter or longer periods also may be used (IPCC 2007). The term "climate change" thus refers to a change in the mean or variability of one or more measures of climate (e.g., temperature or precipitation) that persists for an extended period, typically decades or longer (IPCC 2007). Various types of changes in climate can have direct or indirect effects on species. These effects may be positive, neutral, or negative and they may change over time, depending on the species and other relevant considerations, such as the effects of interactions of climate with other variables (e.g., habitat fragmentation; IPCC 2007). Hellman et al. (2008) listed five mechanism that might change in response to climate change and that might alter a species' invasiveness or management: 1) mechanisms of transport and introduction; 2) climatic constraints on an invasive species; 3) distribution of existing invasive species; 4) impact of existing invasive species; and 5) effectiveness of management strategies for an invasive species.

The challenges in restoring and conserving native aquatic species will likely become more difficult due to the interaction of invasive species and climate change (Rahel et al. 2008). The abundance of nonnative species can increase rapidly under favorable conditions such as low flow prolonged by drought (Moyle and Mount 2007). Droughts are part of the normal climate pattern in the CRB, but they do not occur in cyclic fashion and they are difficult to forecast (CSBCRBWM 2007). However, while the drought of the early 2000s will eventually be followed by wetter conditions, future droughts of varying severity are predicted to recur with increased frequency and duration (CSBCRBWM 2007). Resulting reductions in water stores and stream flows due to climate change will likely intensify demand for remaining water supplies and may hasten proposed water development, including in the Yampa River (NCWCD 2006; Kinsella et al. 2008; Rahel et al. 2008; Palmer et al. 2008; 2009; Repanshek 2009). For example, long-term climate and water development forecasts suggest flow scenarios for the Yampa River that will functionally mimic drought conditions, including reduced stream discharge, smaller stream size, and an increase in summertime water temperatures (Roehm 2004; Johnson et al. 2008).

Martinez (2012) reviewed the implications of reduced stream flows and resulting elevated water temperatures for impacts by invasive virile crayfish *Orconectes virilis* and smallmouth bass in the Yampa River and other similar rivers in the UCRB. Several other invasive species, including green sunfish *Lepomis cyanellus* and largemouth bass *Micropterus salmoides*, have higher thermal tolerances than many of the fish species native to the CRB, and some native species such as speckled dace *Rhinichthys osculus* may be disadvantaged by thermal increases and extended periods of low summer discharge (Propst and Gido 2004; Carveth et al. 2006; Rahel et al. 2008). Species that are widely distributed in the United States, including in the UCRB, such as fathead minnows *Pimephale promelas*, green sunfish, and channel catfish, are projected to benefit from climate change (Eaton and Scheller 1996). The projected increase in channel catfish growth rate (McCauley and Beitinger 1992) could increase piscivory by larger catfish in the UCRB (Tyus and Nikirk 1990). Small-bodied, warmwater nonnative fishes, including the juveniles of larger species, also pose a predatory threat to larval endangered fishes (Karp and Tyus 1990; Ruppert et al. 1993; Brandenburg and Gido 1999; Carpenter and Mueller 2008; Schooley et al. 2008).

Climate change and its effects on water temperature may also alter the dynamics of parasite and disease transmission and host susceptibility, exposing immunologically naïve native fish to outbreaks of pathogens (Marcogliese 2001; Ficke et al. 2007; Rahel and Olden 2008). For example, thermophilic Asian tapeworm *Bothriocephalus acheilognathi* may become more widespread and increase its infection intensity due to higher water temperatures associated with lower summertime flows (Clarkson et al. 1997;

Hoffnagle et al. 2006). Incidence of infection may be higher in small fish and infected fish may grow more slowly, prolonging their exposure to increased infection and predation, and potentially reducing the survival of native cyprinids (Brouder 1999; Ward 2005). Thermal modeling for key invasive species (e.g., northern pike and smallmouth bass) is recommended as a "**medium priority**" to forecast if changes in water temperatures due to reduced precipitation or stream flows will prove beneficial or detrimental to existing invasive species in the UCRB as it relates to the control and suppression of their populations in critical habitat (***NNF1012***). Further, it is recommended that climate changed be emphasized in Recovery Program messaging regarding the need going forward for increasingly preventive measures in the management of nonnative aquatic species due to the anticipated aggravating impact of elevated water temperatures in critical habitat (***NNF1012***).

Electrofishing Evaluation

Concern has been expressed about the potential deleterious effect of the multiple electrofishing passes required for the removal of target nonnative fishes on native fishes. Martin and Wright (2010) expressed concern about potential chronic and/or acute impacts of increased electrofishing on Colorado pikeminnow. Examination of factors contributing to reduced survival of adult Colorado pikeminnow did not identify sampling mortality as problematic (PDO 2006). Similarly, Bestgen et al. (2007a) presented field observations and specific experimental results of other studies indicating that repeated electrofishing associated with development of Colorado pikeminnow population estimates in the Green River basin did not appear to be a significant source of mortality. Additional examination of Colorado pikeminnow data collected during 2006-2008 further indicated that repeated capture by electrofishing did not negatively affect survival of Colorado pikeminnow (Bestgen et al. 2010). Native UCRB fishes may be affected differently by electrofishing. Muth and Ruppert (1996) reported internal injuries and reduce hatching success in razorback sucker shocked at 60Hz and 24% duty cycle. Ruppert and Muth (1997) reported no significant difference in injury or mortality in juvenile bonytails between controls and taxis or narcosis treatments at 30 Hz and 12% duty cycle or 60 Hz and 24% duty cycle. Bohl et al. (2009) reported reduced survival of cyprinid embryos subjected to electroshock, however, 60 Hz PDC, which is recommended for use in UCRB rivers was less harmful and has been shown to be minimally harmful with repeated use (Gatz and Linder 2008). Investigating the effects of the repeated use of electrofishing on native fishes was ranked as "**high priority**" (***NNF0209***).

Hybridization with nonnative fish

At present, the primary threat of hybridization between nonnative and native fishes in the UCRB is between nonnative white sucker and its native sucker species (UDWR 2006). While hybridization between native and endangered razorback sucker may occur in the wild at a low level (Buth et al. 1987), the mass release of any native suckers hybridized with nonnative suckers would threaten gene pools of wild native or endangered suckers in the UCRB. Hybridization between sucker species native to the UCRB with the nonnative white sucker is known to occur (Douglas and Douglas 2003; McDonald et al. 2008; Quist et al. 2009). Hybridization of closely related native species or with nonnative species reduces genetic integrity and reproductive fitness of individual native species and may endanger rarer species through outbreeding depression (Perry et al. 2002, McDonald et al. 2008, Muhlfeld et al. 2009). Thus, hybridization may pose an additional threat to the native aquatic community required to promote and sustain recovery of UCRB endangered razorback sucker (USFWS 2002d). McDonald et al. (2008) revealed that hybridization of native bluehead and flannelmouth suckers with the white sucker increased introgression between the native suckers. This mechanism could ultimately pose an increased threat of hybridization for razorback sucker (USFWS 2002d).

Incidental removal of white suckers and their hybrids in the UCRB at the selective fish passages on the Colorado and Gunnison Rivers and those captured by electrofishing in the Green and Yampa rivers is recommended as a "**high priority**" as an index of their population status and to reduce their numbers (***NNF1012***). Initially, standardizing the criteria and identification key used by field personnel to identify hybrid suckers is recommended as a "**high priority**" to potentially provide a means for tracking the percentage of sucker hybridization in the UCRB overall or more specifically between individual species in specific locations (***NNF1012***). The use of genetic techniques is recommended as a "**low priority**" (***NNF1012***) to monitor the integrity/ introgression of native sucker species (Cooke et al. 2005; Turner et al. 2009). Examination of white sucker maturity in relation to age and size through examination of gonads and fin ray sections to potentially focus removal by size of fish is recommended as a "**medium priority**" (***NNF1012***).

Population and food web impacts to native aquatic communities

Nonnative and invasive aquatic species may impact native fishes in several ways. They may compete for environmental resources of native fishes through exploitative competition for food, interference competition for feeding sites or shelter, or by apparent competition (hyperpredation) which intensifies and sustains predation on native fishes by a nonnative piscivore(s) (Bryan et al. 2002, Carpenter 2005, Martinez 2012). Further, nonnative fishes may harbor exotic diseases or parasites which may reduce vitality of native fishes, contributing to increased mortality (Ward 2005, Hoffnagle et al. 2006, Rahel and Olden 2008). Native fishes of the Colorado River basin appear to lack competitive and predator defense abilities compared to fishes that evolved in more species-rich regions (Moyle 1986; Minckley and Douglas 1991; Johnson et al. 1993; Rogowski and Stockwell 2006; Pilger et al. 2008). Native Colorado River warmwater cyprinids and catostomids co-evolved with a single piscivore, Colorado pikeminnow, while many of the introduced nonnative species evolved in fish communities containing many predatory fish species (Clarkson et al. 2005). Introduced predators may have particularly strong effects on naive native prey that do not recognize or respond appropriately to an invader (Moyle and Light 1996; Simon and Townsend 2003; Mueller et al. 2007; Mitchell and Knouft 2009).

Nonnative piscivores appear to be the most negatively correlated with native species and are most likely to alter native fish assemblages and raise extinction risk (He and Kitchell 1990; Moyle and Light 1996; Findlay et al. 2000; Mitchell and Knouft 2009). Predation on early life stages or juveniles of native fishes by nonnative predatory species, including nonnative crayfish and small-bodied fish, or on all life stages by larger predatory fishes, can reduce population numbers by compromising recruitment of young fish or by reducing the number of reproductive adults (Mueller et al. 2006; Carpenter and Mueller 2008; Johnson et al. 2008). The suite of nonnative, large-bodied, predatory fish species in the UCRB, such as smallmouth bass, northern pike, walleye, and burbot may reduce carrying capacity for adult Colorado pikeminnow in critical habitat. Because fishes in lotic systems that are top predators tend to consume energetic resources that are one trophic level below them and assimilate only a fraction of these resources, less energetic resources are available for predator production (McGarvey et al. 2010). Adult predatory fishes that rival the body mass of adult Colorado pikeminnow would be expected to compete for the energetic resources available for top predators within critical habitat (McGarvey et al. 2010). Partitioning available energetic resources among multiple predator species would inevitably be expected to reduce the density of adult Colorado pikeminnow (McGarvey et al. 2010). Research is recommended as a "**low priority**" to better understand the ecological interactions and consequences of partitioning lotic energetic resources between native and nonnative aquatic species (***NNF1012***).

Emerging Techniques

A variety of techniques are being applied, tested or developed for the control of invasive species. Some of the items included here have a longer history of development and application, but they remain novel techniques in the UCRB. Other more recent techniques are presently unproven in their effectiveness in controlling invasive aquatic species, but may become candidates for testing or application for the control of problematic species in the UCRB. Because these techniques are highly varied, only brief coverage is provided here. If a particular technique is to be further considered for application or further research, a literature review, consultation with recognized experts or site visits where the technique is being applied/tested would be recommended as a "**medium priority**" (***NNF1012***).

<u>Genetic biocontrol</u>

Biocontrol, including genetic techniques, was ranked as "**medium priority**" due to its anticipated difficulty of implementation (*NNF0209*). Recovery Program participation in the Genetic Biocontrol Workshop held in Minneapolis, MN in June 2010 (Kantola and Martinez 2010) provided information on the suite of genetic techniques potentially available for the control of problematic populations of nonnative fish (Kapuscinski and Patronski 2005; Thresher 2008). Only a couple of these techniques appeared applicable or potentially pursuable at the present time. The aforementioned triploidy method (Appendix B) can be applied to limit the reproduction of stocked fish, reducing the risk of invasion in the UCRB, but it is typically not capable of inducing a population reduction of reproducing resident fish. However, male triploid fish have testes, producing sperm and hormones that may allow them to be competitors for fertile, diploid females. If behaviorally competitive and reproductively successful, their offspring would not be viable (Feindel et al. 2010), offering the potential for population control if sufficient numbers of triploid males could be stocked. This strategy of stocking triploid males would be highly dependent on their reproductive competiveness and success in mating with fertile, diploid females. Supporting or conducting research on the question of reproductive competitiveness for a non-centrarchid, target species of predatory fish (e.g., walleye) in the UCRB is recommended as a "**low priority**" (***NNF1012***).

It is recommended as a "**medium priority**" that research be encouraged, supported or conducted on autocidal techniques that drastically reduce the ratio of females to males within a population (Thresher 2008; *NNF1012*). This technique may be especially applicable to widespread, problematic species in the UCRB such as channel catfish or red shiner *Cyprinella lutrensis*, which may respond favorably to climate change, intensifying their negative impacts on the native aquatic community. The Trojan Y Chromosome strategy requires species that have XY sex determination and are amenable to sex-reversal (Gutierrez et al. 2012). Sex-reversed females carrying two Y chromosomes are released into the population as a means of eventual eradication (Gutierrez and Teem 2006). The work of Chaimongkol (2009) with channel catfish and common carp (cyprinids) may facilitate the development of "breed-to-extinction" gender ratio distortion similar to the proposed "daughterless carp" technique (Thresher 2008). Engaging in discussion or making a site visit to candidate research facilities (e.g., Auburn University in Alabama) is recommended as a "**low priority**" to ascertain the status of existing technology and the prospects for facilitating or funding genetic biocontrol research for species and applications in the UCRB (***NNF1012***).

<u>Non-physical, stimulus barrier screens</u>

In addition to the physical/structural screens/barriers described above, fish guidance and repelling technology also includes non-physical, stimulus based technologies including electrical fields (shock), flashing lights (strobes), acoustic arrays (sound) and bubble curtains (visual). None of these technologies are known to be in use in the UCRB, but they are increasingly being used elsewhere to repel fish to prevent their entrainment, escape or invasion either singly or in combination as multi-stimulus screen/barrier installations (Turnpenny et al. 2010). There likely are scenarios in the UCRB where this technology is or may become applicable to control movement of problematic nonnative aquatic species. Site specific consideration would include public safety or nuisance concerns, habituation by target species resulting in reduced effectiveness, or potential effect on non-target species (Turnpenny et al. 2010). Application of this technology at the present time in the UCRB for the control of movements by nonnative fishes is recommended as a "**low priority**" (***NNF1012***).

<u>Physical Techniques</u>

Gross et al. (2010) provides a summary of innovative physical techniques that may be adapted to control invasive fishes. Some apply familiar techniques in alternate ways, such as electricity applied to the substrate as opposed to the water column to target fish embryos. Similarly, covering the substrate with fine particulate matter (silting) would deprive embryos of oxygen. Other techniques rely on technology developed for other purposes, such as the use of seismic technology (water guns) to target adult fish. This pulse pressure technology is being evaluated for its effectiveness in suppressing invasive northern pike (Gross 2010), and thus may become of interest for application to concentrations of adult pike in spawning habitats in the UCRB and is recommended as a "**medium priority**" for experimental use (***NNF1012***).

Chemicals

Gross et al. (2010) summarized the potential use of both familiar (carbon dioxide) and lesser known chemicals (peracetic acid) for the control of fish embryos and larvae. Numerous considerations, including the application concentration, potential of application, detoxification requirements, regulatory constraints, toxicity to non-target organisms, etc., would have to be addressed prior to the use of these chemicals as pesticides. However, additional tools to control or eradicate problematic fishes, including targeting early life stages, would contribute to an IPM approach and the application of multiple gear types, which was rated as "**high priority**" (*NNF0209*). Ammonia has emerged as a potential alternative as a pesticide for local eradication of invasive fish (Ward et al 2013) or invertebrates (e.g., crayfish; Clearwater et al. 2008), and further consideration of it use for spot or small-scale treatments is recommended a "**medium priority**" (***NNF1012***).

Invertebrate Control

Techniques and technology to control most invasive invertebrates have yet to be developed for application on large scales, thus prevention is the absolute best method to prevent their invasive impacts. Four of the crayfish species in the Yampa River (virile, rusty *O. rusticus*, papershell *O. immunis*, and ringed *O. neglectus*), for example, are considered to be highly invasive (Larson and Olden 2010, 2011; Gherardi et al. 2011; Martinez 2012). Martinez (2012) described potential impacts of crayfish in the UCRB, and the ecological implications of invasive virile crayfish and the recently invading rusty crayfish (Brown 2011) in the Yampa River basin. New invaders, such as rusty crayfish, should be targeted for early eradication because of unacceptable impacts (Cambray 2003; Strayer et al. 2006; Moyle and Marchetti 2006; Gren 2008). Hyatt (2003) and Gherardi et al. (2011) summarized potential control options for crayfish ranging from trapping to chemical treatments.

Trapping is being employed in Lake Catamount, a reservoir on the upper Yampa River, in an effort to eradicate rusty crayfish (B. Atkinson, Colorado Division of Wildlife, personal communication). Zipkin et al. (2009) categorized rusty crayfish as good candidates for eradication/control efforts due to their low propensity for population overcompensation in response to harvest. Control of crayfish was among the highly recommended strategies, but it was ranked as "**low priority**" due to uncertainties about treatment costs or effectiveness (***NNF0209***). However, given the nonnative status of crayfish in the Colorado River Basin and their invasive capacity and potential to negatively reconfigure native lotic food webs, it is recommended as a "**high priority**" (***NNF1012***) that all states in the UCRB should prohibit the importation, movement, sale, possession, and stocking of any live crayfish (Martinez 2012).

Biocontrol

The potential use of biocontrol options to control/eradicate problematic nonnative species, including species specific or genetically modified diseases or parasites, predators or competitors, or behavioral chemicals to attract or repel target species, has received little attention in the UCRB and is considered to be "**low priority**" (***NNF0209***). One initial example attempted the use of white sucker as a pheromone source to bait northern pike, but was unsuccessful and suggested the use of mature adult pike as potential attractants to increase the catch of pike (Martin and Wright 2010). It is recommended as a "**low priority**" that future applications of such techniques be undertaken experimentally to evaluate their potential utility for target species in the UCRB (***NNF1012***).

Environmental DNA (eDNA)

Eradication and control of an introduced species is more likely to be successful if it is detected early when its spatial distribution is restricted and its abundance is low (Myers et al. 2000). However, this limited distribution and abundance may hinder early detection (Hoffman et al. 2011). Environmental DNA in suspended, sloughed tissues may allow detection of even rare organisms in aquatic environments that may remain undetected by traditional sampling methods (DeJean et al. 2011; Jerde et al. 2011). Further, eDNA may have potential to estimate species biomass, allowing detection of seasonal concentration of target species in reproduction, feeding or refuge habitats (Takahara et al. 2012). It is recommended as a "**low priority**" that the utility of this technology in the UCRB be considered after its adoption becomes more widespread (Darling and Mahon 2011; ***NNF1012***).

IV. Policy and Enforcement

Presently, the primary method for encouraging more pro-active Recovery Program policies is the annual Sufficient Progress Memo (USFWS 2011b). This document identifies and evaluates both accomplishments and deficiencies of the coordinated efforts to determine if ongoing recovery actions are sufficient to offset effects of water depletions. This annual evaluation applies primarily to the recovery status of endangered fishes falling under the jurisdiction of the ESA and the USFWS. Achieving an enduring recovery of endangered fishes in the UCRB will be dependent on a relatively intact native aquatic community of species which falls under the self-regulation jurisdictions of the states of the UCRB. Because of the complex and sometimes conflicting missions of fishery agencies in providing both recreational and conservation services for aquatic resources (Clarkson et al. 2005; Carey et al. 2011), their responsiveness or self-enforcement in implementing or adhering to effective policies, regulations and enforcement to improve prevention strategies for invasive species to native aquatic communities may be confounded (Carey et al. 2012). This scenario may ultimately inspire or invite adapting or adopting new regulations or enforcement strategies. It will also require appropriate preventive and remediation responses to preserve native aquatic communities, sustain recovery, and prevent future listings under the ESA. Ultimately, management of endangered fishes upon their recovery will transition from primarily federal responsibility for the implementation of nonnative aquatic species control to ongoing implementation by the UCRB states. Preparation for this transition was ranked as "**medium priority**" (***NNF0209***).

Cross-jurisdictional Coordination

Responsibility for invasive species policy is often divided among a number of agencies, a regulatory approach that discourages an integrated or uniform approach to prevention and control (Goodhue and McKee 2006; Kaiser 2006). In the case of the UCRB the jurisdictional unit is primarily at the state level, although multiple agencies may be involved (e.g., wildlife, agriculture). A problem arises when deficient regulations in one jurisdiction increase the risk of introductions or invasive impacts region-wide in adjacent jurisdictions (Peters and Lodge 2009). Ultimately, the probability for success of an individual state's efforts to prevent invasive species as part of efforts to recover endangered fishes or preserve native aquatic species in the UCRB is multiplied by their neighbor's similar or stronger effort. Coordinated management is recommended as a "**high priority**" (***NNF1012***) in the UCRB to prevent invasive impacts to native aquatic species by nonnative aquatic species in accordance with ecological considerations rather than along political boundaries (Davies and Jackson 2006; Gersen 2009).

On a national level, crayfish regulations pose another example of how cross-jurisdictional coordination could be improved (DiStefano et al. 2009; Peters and Lodge 2009; Larson and Olden 2011. Crayfish regulations in the UCRB also display this inconsistency (Martinez 2012). No crayfish species are native to the Colorado River basin and their deleterious impacts to native aquatic food webs are increasingly recognized (Martinez 2012). While the regulatory situation for crayfish has improved recently to include more states with prohibitions on the transport of live crayfish (AZ, CO, UT), other states only prohibit the movement of rusty crayfish *Orconectes rusticus* (NM, WY), which can be difficult to distinguish from other species in the field (DiStefano et al. 2009; Peter and Lodge 2009). Further, commercial transport or importation of live crayfish for the aquarium and food trades may be unaddressed by existing regulations intended to prevent species introductions. Martinez (2012) recommended that all movement of all live crayfish be prohibited for any purpose in the UCRB. Reviewing and modifying crayfish regulations in the UCRB was ranked as "**medium priority**" (***NNF0209***).

Inconsistent coordination can apply to jurisdictional policies and practices as well. Northern pike, for example, are highly problematic for native fishes in the Yampa River, and it would be ill-advised to allow their establishment or invasive impacts to manifest in other UCRB locations. Despite this, fishing for northern pike continues to be promoted in rivers and reservoirs in the UCRB. While this promotion is tempered in some cases with the message that northern pike can be problematic for native or sport fishes, the species is disparately promoted among the UCRB states. In some cases, illegally established populations of northern pike are promoted. This promotion may entrench an expectation among anglers that such fisheries be perpetuated, despite the invasion risk or the existing invasive impacts in critical habitat. The development of a consistent, cross-jurisdictional approach to aquatic invasive species prevention and control was ranked as a "**high priority**" (***NNF1012***). Also, the need for information and education about predatory impacts was ranked as "**high priority**" (***NNF0209***).

Illegal Introductions

Appendix H summarizes the current extent of the problem of illegal introductions in the UCRB and shows that this illegal activity has been escalating (Table H-2). In addition, the most highly piscivorous nonnative species in the UCRB, northern pike, smallmouth bass, and walleye, ranked as the species that posed the greatest threat to prospects for endangered fish recovery and native fish preservation in the UCRB due to their piscivory in rivers, invasiveness in riverine habitats, and their high incidence of illegal transfers into ponds and reservoirs (Appendix H, Table H-3). Illegally introducing fish has increased the propagule pressure of these predatory species in the UCRB and the likelihood that their distribution and abundance in critical habitat will expand. This risk will be compounded if this problem proceeds unchecked, increasing recovery costs for endangered fishes and management costs to prevent future listings of additional species.

Illegal introductions impart additional management complexities for both native and sport fish management. Northern pike, for example, can greatly impact established, comparatively innocuous sport fisheries based on species that may be approved under the Stocking Procedures for the UCRB (Appendix Table C-1), such as salmonids, largemouth bass, bluegill or yellow perch (Pauckert and Willis 2003; Debates et al. 2003; Flinders and Bonar 2004, 2008). Sport fisheries typically respond positively to removal and reductions in northern pike (Jolley et al. 2008; Kuzmenko et al. 2010). Golden shiner *Notemigonus crysoleucas*, illegally introduced into Rifle Gap Reservoir (Appendix Table H-2), appear highly resistant to predation by both centrarchids and northern pike (He and Kitchell et al. 1990; Findlay et al. 2000), and may pose an unforeseen threat to native fishes if they escape from the reservoir and become established in the rivers of the UCRB.

Illegal stocking subverts the preventive measures found in the Stocking Procedures (USFWS 2009). Resolutions adopted by the American Fishery Society's Colorado-Wyoming Chapter (CWAFS 2007) and Western Division (WDAFS Resolution; Appendix H, Figure H-1) to address the problem of illegal introductions illustrate the perception among fishery professionals regionally that this problem is in need of urgent attention. Illegal stocking represents a major pathway that may not only increase the distribution and abundance of problematic fish species, but may also transfer other undetected, hitchhikers. Either of these avenues, illegal transport or invasive hitchhikers, could expand existing problems, further threatening native aquatic communities and risking ruin of existing, productive sport fisheries.

Increasing penalties for illegal introductions and reducing or eliminating the incidence of illegal introductions were both ranked as "**high priority**" (*NNF0209*). The Sufficient Progress Memo for 2010-2011(USFWS 2011b) acknowledged that illegal introductions of nonnative aquatic species continues in the UCRB and poses significant risk to endangered fishes. Michalski (2007), Johnson et al. (2009), and the WDAFS Resolution offer a variety of potential strategies to address this problem, but adoption of many of these tactics have not been undertaken or uniformly applied in jurisdictions of the UCRB. Wyoming's 2010 implementation of more severe penalties ($10,000 fine) for "stocking fish without consent", Utah's implementation of must-kill policies for burbot statewide in 2011, and Colorado's must-kill regulation for crayfish in the western part of the state in 2011 to reinforce the prohibition against movement of rusty crayfish represent positive and proactive steps to help address the problem of illegal introductions. But it is recommended as a "**high priority**" that this effort in the UCRB will be greatly strengthened through a consistent educational message, more uniform regulations and severity of penalties, and a coordinated approach to surveillance, informant incentives, and enforcement (***NNF1012***).

Attempting to detect and prosecute illegal stocking after the fact can be difficult and may forego actual costs of restitution if the establishment and invasion by the illegally introduced species is delayed, unwitnessed, or repetitive. Consistent policies in the UCRB addressing education, increased enforcement, informant incentives, and more severe penalties for the live transport of nonnative aquatic species is recommended as a "**high priority**" (***NNF1012***) to intervene at an earlier, more preventable stage of the act and violation of actually performing the act of illegally releasing, stocking or introducing species that may/will prove problematic for sport, native or endangered fishes by subsequent expansion, escapement or invasion. The seriousness of illegal stocking does not appear to be well understood by the judicial system. Utah recently convicted an individual of illegal introduction of a nonnative species of trout. That individual was found guilty, but only fined ~$300. Program partners should work with the court system to develop a better understanding of the ecological / financial damage caused by illegal introductions; wrecommended as a "**high priority**".

Illegal Introductions - Water quality model for nonnative/invasive species

Preventing invasive species introductions to promote and preserve native aquatic species may not reach the same level of public, political or administrative awareness or regulatory support devoted to preventing water contamination that diminishes conditions for aquatic life or human use, but there are emerging analogies. Some nonnative species are more dependent on source populations in reservoirs to maintain their presence or abundance in stream and rivers (Gido and Franssen 2007), but they nonetheless add to the cumulative impact on lotic food webs that support native and endangered species (McGarvey et al. 2010). In analogous water quality terminology (Chapman 2007), nonnative species introduced into or entering habitats valuable for preserving native species whose community effects may range from innocuous to incidental can be viewed as "biological contaminants". But even these species should be avoided due to the risk of introducing diseases or parasites. Often, the sporadic persistence of "contaminant" species can be attributed to a point source(s). Invasive species that increase in distribution and abundance, resulting in adverse biological effects in the aquatic community can be viewed as "biological pollutants" (Jenkins 2002; Horan and Lupi 2005; Davies and Jackson 2006; Chapman 2007).

Invasive species may also originate from a single point source, but unlike industrial or municipal pollution that would be most concentrated nearest the source and diminishing in concentration as it dispersed downstream, many invaders can move into and reproduce in both upstream and downstream habitats without further anthropogenic assistance, thus becoming non-point pollutants (Finnoff et al. 2005). Because such species can individually or cumulatively reconfigure native aquatic food webs to the detriment of native fish communities as their numbers and deleterious effects increase, sometimes far from their initial point of invasion, they should be viewed administratively and ecologically as "proliferative pollutants". While preventing all water pollution or biological pollution by nonnative species is economically infeasible (Shogren and Tschirhart 2005), it is recommended that new introductions or reintroductions of known problematic species in the UCRB be avoided.

This concept of illegally introduced or escaped fish as pollutants has scientific and legal precedent, but regulatory reform due to transboundary issues among jurisdictions has proven challenging (Barry and VanderZwaag 2007). Brinninkmeyer (1999) viewed fish that escaped from salmon farms as pollutants originating from a point source and argued for better containment or the use of sterile fish that would not reproduce in the wild. Further, escaped salmon were viewed as agricultural or industrial waste on the basis that courts have declared, in some instances that live fish that had escaped constituted biological pollution. Firestone and Barber (2003) asserted that intentionally stocked fish, accidentally released fish or fish that have escaped represent point sources of pollution when they reduce native fishes in habitats that otherwise remain well suited to the native species. They further acknowledged that sport fish tend to be viewed positively regardless of their role in ecosystems, but anticipated that philosophical, scientific and legal challenges to the status quo are warranted and should be expected. Recognizing and identifying nonnative aquatic and terrestrial species which have become problematic for endangered fish recovery as "biopollutants" may be a useful concept for I&E efforts.

Native Fish Conservation Areas

Martinez (2006, 2007) proposed the designation of conservation areas within critical habitat for endangered fishes in the UCRB to elevate public and agency awareness about the management needs of native fishes, primarily nonsalmonid species, and to promote the protection of these vulnerable species and the habitats needed for their preservation. Analogous protective designations exist and are widely recognized by anglers and agencies for native and nonnative salmonids in the form of gold medal waters that restrict harvest, wild trout waters that restrict stocking or as native cutthroat trout water that restrict both harvest and stocking to maintain their numbers and genetic integrity. These designations often carry messages about the need to protect or enhance the habitat, along with penalties for the degradation of these habitats. Similarly, the application and recognition of protected areas for nonsalmonid native species could be used to promote the preservation of native aquatic communities within critical habitat and adjacent waters in the UCRB.

The continued decline of native fishes in the UCRB suggests that additional, proactive management approaches that address entire fish communities rather than the individual species approach of recovery actions are needed (Dauwalter et al. 2011). The basin aquatic wildlife management plans for the major rivers in the UCRB within Colorado functionally designate the lower reaches of these rivers, including adjoining reaches of some tributaries, as native fish conservation areas. These basin plans for the Colorado (CDOW 2003a), Gunnison (CDOW 2003b), San Juan (CDOW 2003c), and Yampa (CDOW 2010), prioritize the management of the native, warmwater assemblage of cyprinids and catostomids and state the need to control nonnative fishes. However, this native fish emphasis in these lower river and tributary reaches, which encompass critical habitat for endangered fishes, is not promoted and remains obscure to the public, anglers and agencies. Designation and promotion of native fish conservation areas are not only intended to facilitate perseveration of native aquatic communities and their habitat, but to shift away from the sole concept of a federal legal designation to a multi-agency, multi-state recognized, embraced, and protected resource. The emphasis on preserving the ecological integrity of the native aquatic community to promote and sustain recovery of endangered fishes, and to deter future listings under the ESA, would become more prominent through cooperative designation and widespread recognition of native fish conservation areas in the UCRB.

> *When discussing NFCA within the Recovery Program a common stumbling block has been - **what would such a designation mean?** The UDWR offered the following tenets they think would help define a NFCA: 1) States will not manage or promote the nonnative species within the designated area; 2) A rapid response plan will be implemented when a "new" or problematic species is documented in the NFCA; 3) The NFCA will be promoted in the Fish Proclamation (or like documents); 4) A must kill regulation for NOP, burbot, walleye, smallmouth bass, channel catfish will be enforced in the NFCA; 5) The NFCA will be promoted through media 6) Coordination with Native American tribes will be required where applicable (e.g. the lower 24 miles of the White River).*

Williams et al. (2011) stressed the importance of native fish conservation areas (NFCAs) to reverse the trend of declining native fishes, to facilitate recovery of threatened and endangered aquatic species, and to protect native aquatic communities while allowing compatible uses. Four critical elements for NFCAs were identified including 1) providing for habitat complexity and connectivity, 2) addressing all life stages of the fishes to be protected, 3) incorporating watersheds of sufficient scale for long-term persistence of native fish populations, and 4) applying management that is sustainable over time. While designated critical habitat provides some legal protections for endangered fishes and their habitat, its specific focus on individual endangered species fails to instill the urgency to protect the native aquatic community required to facilitate and sustain recovery or prevent future listings of native aquatic species. Designating native fish conservation areas may improve both public and agency awareness about challenges facing native fishes and was ranked as a "**high priority**" (***NNF0209***).

V. Information and Education

Efforts to inform and educate the public about the work of the Upper Colorado River Recovery Program are strategically developed by the Information and Education (I&E) Committee. According to the *Recovery Implementation Program Recovery Action Plan (RIPRAP; Amended March 25, 2011)*, the goals of the Information and Education program are:

1. Develop public involvement strategies at the beginning of any and all projects.
2. Educate target audiences (including media, the public and elected officials) about endangered fish and increase their understanding of and support for the recovery of these fish at local, state and national levels.
3. Provide opportunities for the public to participate in activities that support recovery
4. Improve communication and cooperation among members of the Recovery Program

In addition to the RIPRAP guidance, the work of the Recovery Program to educate and inform the public is generally guided by an annually adjusted, overall scope of work (*PIP-12 Information and Education*). Efforts related to communicating about nonnative aquatic species are detailed in a separate scope of work (*PIP-12L Nonnative Fish*). These scopes of work are intentionally structured as public involvement plans (PIPs).

The Nonnative Fish Management Policy (Adopted by the Implementation Committee, Feb. 2004) states that "a comprehensive public communication and involvement plan on nonnative fish management has been developed by the Recovery Program… and implementation of this plan will assure that the public understands what is being done and why, and has confidence that the process is driven by science and is clear, open and honest. Additionally, the document lays out the following policy for Recovery Program Information and Education:

> *6. Agency and public understanding of the purpose and scope of nonnative fish management actions by the Recovery Program and its participating agencies is critical to the success of the effort. Recovery Program partners agree to support and actively participate in public communication and involvement.*

Prior to 2003, communication messages regarding nonnative fish typically focused on basic facts (e.g., there are more than 50 nonnative fish species in the UCRB; nonnative fish species have contributed to declines in endangered fish populations; some nonnative fish prey upon endangered fish or compete with native fish for food and space). Recovery Program communications also focused on early research and removal messages to advise the public regarding specific activities that were occurring.

Since 1997, U.S. Fish and Wildlife Service staff has promoted awareness of Recovery Program work through participation in Ute Water's annual children's water festival event in Grand Junction. The event provides an opportunity to highlight the differences between native and nonnative fishes. Other in-person events also provide opportunities to share information in a one-on-one environment. To that end, information is provided during the Colorado Water Congress annual meeting in Denver, the Colorado River Water Users Association annual meeting in Las Vegas and the Utah Water User Workshop in St. George.

Since 2000, elementary and high school classes in western Colorado have raised endangered razorback sucker or Colorado pikeminnow in classroom aquariums during the school year and released them into the river each spring. This school program is run through Colorado Parks and Wildlife. Since 2003, the Recovery Program has shared the costs for aquarium supplies.

In 2005, the Recovery Program produced a bookmark-sized information piece targeted at boaters in Dinosaur National Monument. This resulted in better acceptance among boaters in the Monument who had previously complained about the noise from researchers' equipment.

Beginning in 2003, the Recovery Program prepared and implemented a comprehensive communications plan to raise public awareness about the purpose of nonnative fish management. Efforts included developing informational materials and posting them on the Recovery Program's public website; informing members of Congress and other elected officials; and proactively seeking news media coverage, including inviting reporters to accompany biologists as they conducted their work. In 2003, public meetings were held in Grand Junction, Steamboat Springs and Craig, Colorado. The Utah Division of Wildlife Resources developed and implemented its own communication plan to support the Recovery Program's communication efforts. The plan included presentations at Regional Advisory Council meetings in Green River and Vernal, Utah.

In August 2006, a public meeting was held in Craig, Colorado, to address the public's concerns about nonnative sportfish removals. The meeting was orderly with only a few members of the public in attendance.

In August 2007, a public meeting was held in Grand Junction, Colorado. The purpose of the meeting was to provide information to anglers in the area who continue to believe that the Recovery Program is removing their preferred sportfish. Only four members of the public attended.

In 2009, the Information and Education Committee began redesigning communication products to stress tangible benefits of the Recovery Program while pointing out that nonnative fish removal is necessary to achieve those benefits. The new key messages stressed: recovery of four endangered fish species found only in the Colorado River basin; continuation of water development while recovery occurs; and the collaborative program that is a model for other endangered species recovery efforts.

In 2011and 2012, key messages and Recovery Program 'Frequently Asked Questions' were updated to better reflect an emphasis on prevention. The Recovery Program issued two versions of a news release related to nonnative fish management. The Colorado version announced that smallmouth bass would not be translocated to Elkhead Reservoir due to research findings that showed many smallmouth bass placed in the reservoir in past years subsequently escaped over the spillway during periods of high flows and reentered the Yampa River. The Colorado Division of Wildlife spoke with the manager of Elkhead State Park and other key stakeholders in advance of the news release to explain the reason for this change and the science behind it. The Utah version of the press release announced that projected high flows from higher than normal snowpack in the Green and Yampa River sub-basins may help the endangered fishes by reducing populations of some species of nonnative fishes.

Also in 2012, the Recovery Program's Water Users representative convened a group of Upper Yampa River drainage interested parties (Water District representatives, Trout Unlimited, Bass Masters, TriState, City of Craig, CPW, the Recovery Program Director's Office) to discuss how persistent threats from nonnative fish were delaying progress to endangered fish recovery and therefore compromising Section 7 compliance for water use. The goal of those meetings was to openly discuss (i.e. non-binding) potential solutions to address the problem. Although the outcome of those meetings remains to be determined, preliminary indications suggest that the 'messenger' could prove to be a key component in the successful delivery of the message.

Messaging basics

Communicating with the public and helping to educate people about efforts to manage nonnative fish is an important part of the work of the Recovery Program's Information and Education Committee. In addition to nonnative fish messages, the committee is responsible for working with partners on communication and education related to the larger Recovery Program including, but not limited to: lifecycles and biology of the four endangered species; native fish habitat; diversion-structure mitigation; water management including coordinated reservoir operations; and hydropower generation. Nonnative fish management is a critical component of messaging as nonnative fish have been deemed the most significant remaining threat and obstacle to species recovery.

Consistent and creative nonnative fish messaging is important to the overall goals of the Recovery Program; however it is not the only, nor the easiest, communication need faced by the Recovery Program. Some of the opinions that people living or recreating in the UCRB have formed are based on long-held beliefs, attitudes and values regarding the desirability of sport fishing for popular nonnative fish. Changing these long-held beliefs, attitudes and values is complex (Fishbein 1967, 1973, 1980; Fishbein & Ajzen, 1975). It is also widely understood by social scientists that merely providing information is not sufficient to change people's opinions on an issue (Ajzen 1992; Holbrook et al. 2005). Even attending programs that provide a large amount of additional information has been shown to have little impact on participant attitudes (Cable and Knudson, et al. 1987; Knapp and Barrie 1998; Morgan et al. 1997; Orams 1997; Peart 1984; Pettus 1976; and Wiles and Hall 2005).

Much of the prevalent social research finds that strongly thematic information must be developed and must be very relevant to what people know and care about to begin to change their beliefs about related issues (Ham 1992). To better reach these kinds of relevant themes, Recovery Program key messages were developed based on the issues of (1) beneficial water development, (2) beneficial species recovery and (3) the Recovery Program's status as a model for other endangered species recovery efforts across the country. These messages are deemed by the Information and Education Committee to be more effective at opening a dialogue with stakeholders versus the less-effective messaging related to nonnative control, which is viewed by the vocal angling/business public in the critical reaches of the UCRB as a negative consequence of recovery. By raising public support through the *related themes* of water use and benefits of species recovery, the I&E committee believes and the literature supports that it is more possible to change the long-held beliefs related to other program issues such as nonnative control (see Ham and Weiler. 2005; Cacioppo and Petty 1989; and Cacioppo et al. 1994).

Effective message development is critical and multiphase. Initial messaging is designed to highlight Recovery program benefits but secondary messages regarding nonnative fish management, prevention of nonnative introductions, damage caused by illegal stocking of nonnative species, critical habitat designations, implications of climate change and future native fishery opportunities may need to be developed and released in conjunction with the primary messages.

In the 1990s, an attitudinal survey was conducted to determine public values of the Recovery Program. Repeating the survey could be useful in assessing communication success and shortfalls, and would have some benefits for further shaping Recovery Program messaging. Additionally, better communication uses for such an outlay would need to be considered by the I&E committee. Beyond the attitudinal survey, a socio-economic analysis of endangered fish recovery could also prove beneficial for shaping messaging.

Merely developing messages is insufficient to spur a change in public attitude or a change in specific behavior. In addition to the need for message relevance, repetition, integrity and innovation, messages must also be effectively delivered.

The concept of educating the public about nonnative fish impacts is important, and may be capable of changing attitudes. Campaign success varies widely, but development and funding of a large education effort should be researched and similar campaigns at a regional and statewide level should be assessed.

The I&E Committee may choose to conduct a Human Dimensions Study to identify a messaging approach that has the greatest probability of long term success. On

Cornell University's Human Dimensions of Natural Resources website (http://www.human-dimensions.org/) they describe the issue as follows:

> *Human Dimensions of Natural Resources is a reference to the social attitudes, processes, and behaviors related to how we maintain, protect, enhance, and use our natural resources. Today's natural resource managers are increasingly recognizing that natural resource management involves not only ecological processes,but also social processes and consequences as well. In a very basic sense, Human Dimensions examines how the "science of human systems" or theory-based social science can aid in natural resource management.*

Currently, the Recovery Program relies on two main communication efforts to reach the general public: press releases and partners. Press releases are effective communication tools but don't allow for message control through media outlets and press releases may or may not reach necessary audiences. Partner communication can be leveraged and is important, but Recovery Program partners are facing declining budgets. Many agencies are losing dollars in the area of conservation messaging while marketing outreach funding to generate revenue is emphasized. Conservation is often viewed as a 'luxury'.

Marketing strategies proposed

To effectively communicate the reasons for the importance of nonnative fish management efforts in the UCRB, the Recovery Program must first communicate the need for the Recovery Program itself. As previously explained, the key messages are crafted but lack a delivery method to reach the general public. Additionally, follow-up attitudinal research has not been conducted to determine the effectiveness of past communication efforts nor provide a baseline for future marketing campaigns.

Without marketing funding, the I&E Committee and partner agencies should continue to develop communication strategies and materials based on specific goals and objectives that focus on target audiences and include measurable outcomes to the extent possible. While this Strategy cannot list or anticipate all communication strategies, the following strategies could be implemented. The strategies laid out below would serve to inform a small portion of the public and also to make internal constituents feel better about the work of the Recovery Program.

- The Recovery Program I&E committee could develop a one-page flyer or advertisement that highlights the benefits of the Recovery Program as explained through the previously developed key messages. This flyer can be distributed throughout the UCRB by staff members who can post the flyers on community bulletin boards or in other places frequented by the public.
- The Recovery Program I&E committee could develop a web page separate from the existing website that would be geared more toward public education about the messages such as:

- NNF management
- prevention of nonnative introductions
- critical habitat designations
- proper fish locations
- future native fishery opportunities
- implications related to climate change

- The Recovery Program I&E Committee should develop a list of potential communication partners outside of the Recovery Program. These potential partners should be contacted to team on communication efforts, especially those related to non-native fish control.
- The Recovery Program I&E Committee should consider conducting a Human Dimensions to develop an effective communications plan for difficult issues (e.g., illicit introductions).
- The Recovery Program partners could be asked to issue press releases related to the predatory impacts by nonnative piscivores on native and endangered fishes. This was ranked as "high priority" in Appendix A (Figure A-2; Table A-1).
- The Recovery Program partners should be encouraged to issue press releases that explain why species such as northern pike (predation on adult native fish), smallmouth bass (hyperpredation on small-bodied native fishes), crayfish (apparent-competition with small-bodied native fishes), and white sucker (hybridization with native catostomids) are problematic in the UCRB.
- Efforts to educate children and anglers about native fishes should continue and is ranked as "high priority" in Appendix A (Figure A-2; Table A-1).
- If implemented under the other sections of this document, the I&E committee and its member partners should identify ways to communicate the concepts of native fish conservation areas, compatible and non-compatible species lists, and other new management tools.
- The I&E committee will work with partners to eliminate mixed messages in policy and promotion. For example, the committee will discuss examples that come to light where partners promote positives of non-native fishing opportunities absent strong messages regarding the need for protecting endangered fish populations. Additionally, the I&E committee should work in conjunction with the biology committee and the management committee to address policy revisions that might be needed by partner agencies or organizations.

Summary: Basinwide Strategy

The downlisting of UCRB endangered fishes will require meaningful reductions in the abundance, distribution, and sources of nonnative aquatic species and their negative ecological impact to the native aquatic community to remove the impediment they pose for recovery. The USFWS has begun discussions about the potential downlisting of Colorado pikeminnow, but the biggest obstacle may become the existing and future threat of invasive ecological impacts by nonnative aquatic species, particularly predatory sport fishes. It could be argued that the pace of progress has been too slow, particularly as species known to be problematic in one sub-basin begin to invade in another sub-basin. This Basinwide Strategy is intended to accelerate progress to remove the invasive impacts and threat of nonnative fishes in the UCRB to an extent that they are no longer an impediment to recovery over the next decade. The current approach needs to expand to incorporate concepts of invasive species prevention. The probability of success will also be improved through a diversified approach employing more of the available techniques, including treating source populations, incorporating the concept of propagule pressure as a measures of success, and better messaging (e.g., "must kill" regulations, a Stop Illicit Introductions campaign, etc.). Many of the changes in the current approach to nonnative fish management in the UCRB need to be made through changes to State policies and regulations. This Basinwide Strategy capitalizes on: 1. efforts to address nonnative aquatic species in the UCRB during the past two decades, 2. information exchanges in the Recovery Program's Nonnative Fish Workshops during the past decade, and 3. on scientific information to support its recommendations and provide guidance to implement the changes, policies and practices needed to reduce the impacts and threats of nonnative aquatic species in the UCRB. Ultimately, overall success of this strategy (in concert with all other recovery actions) will be measured by meeting the demographic criteria identified in the USFWS's endangered fish recovery plans.

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APPENDIX A

Consideration of the nonnative, large-bodied, predatory fish density in occupied critical habitat relative to recovery goals for Colorado pikeminnow in the Upper Colorado River Basin

Demographic criteria in the draft Recovery Plan for the Colorado Pikeminnow (*Ptychocheilus lucius*), dated 24 June 2012 (hereinafter Draft Plan), include a proposed minimum viable population (MVP = 3,000) for adult Colorado pikeminnow (≥ 450 mm TL) in the upper Colorado River basin (UCRB) and estimates of carrying capacity for adult Colorado pikeminnow in the Colorado and Green River sub-basins (Valdez at al. 2012). These population parameters were compared with mean estimates of adult Colorado pikeminnow abundance contained in the Draft Plan on the basis of density, expressed as the number of adult Colorado pikeminnow per rivermile. These comparisons were made for critical habitat occupied by Colorado pikeminnow in the Colorado (241 rivermiles) and Green River (587 rivermiles) sub-basins and within the UCRB (828 rivermiles).

Annual population estimates and their low and high bounds provided mean, minimum, and maximum population densities to compare the two sub-basins and a mean density for the two basins representative of average ecological conditions in the UCRB (4.2/rivermile; Table A-1). Similarly, carrying capacities for adult Colorado pikeminnow in the UCRB (Draft Plan) provided estimates of minimum, maximum, and mean densities that might be sustained in the two sub-basins and under average conditions the UCRB (5.3/rivermile; Table A-1). The difference between the mean population estimate of adult Colorado pikeminnow and the MVP density (3.6/mile) was 1.1/mile (Table A-1). The difference between the mean carrying capacity of adult Colorado pikeminnow and the MVP density was 1.7/mile. These density comparisons suggest that the UCRB may have a relatively low productive capacity to sustain adult Colorado pikeminnow at a density much exceeding that of the MVP, suggesting that the top predator trophic level in the UCRB should be reserved for Colorado pikeminnow to promote their population security, stability and resiliency. Further, there could be competition for energetic resources from low densities of large-bodied nonnative predatory fish species within the top trophic level occupied by adult Colorado pikeminnow within the UCRB, resulting in local population displacement or broader ecological replacement of adult Colorado pikeminnow.

Large-bodied nonnative predators present and capable of occupying the top trophic level in UCRB critical habitat whose body mass rivals that of large-bodied Colorado pikeminnow (recruit-size to large adults; 425-650 mm TL at about 550-2,000 g) include burbot (450-675 mm TL; Luecke and Mears 2011), northern pike (450-700 mm TL; Johnson et al. 2008), smallmouth bass (325-474 mm TL; Johnson et al. 2008), and walleye (375-550 mm TL; Leucke et al. 2001). A published fish density model (McGarvey et al. 2010; 2011) supported the importance of competition among top predators in lotic systems and suggested that partitioning available energetic resources among multiple predator species would inevitably reduce carrying capacity for Colorado pikeminnow. Examination of historic and recent trends in densities of large-bodied Colorado pikeminnow, northern pike, and smallmouth bass in the middle Yampa River suggests that large-bodied invasive predators have functionally replaced Colorado pikeminnow as the river's top predator.

Table A-1. Estimates of mean adult Colorado pikeminnow (≥ 450 mm TL) carrying capacity and abundance in the Green and Colorado rivers and for both rivers within occupied critical habitat in the upper Colorado River basin (UCRB) obtained from the draft Recovery Plan for Colorado pikeminnow (Valdez et al. 2012).

River and UCRB	Estimated carrying capacity for adult Colorado pikeminnow in occupied critical habitat in the UCRB			Adult Colorado pikeminnow mean population estimates (1992-2010)			Difference between adult Colorado pikeminnow mean carrying capacity and mean population estimate		
	Low	**High**	**Mean**	**Low CI**	**High CI**	**Adults**	**Low**	**High**	**Mean**
Green	3,000	4,500	3,750	2,196	3,698	2,843	804	802	907
no./mile >	5.1	7.7	**6.4**	3.7	6.3	**4.8**	1.4	1.4	**1.6**
Colorado	500	800	650	475	959	658	25	- 159	- 8
no./mile >	2.1	3.3	**2.7**	2.0	4.0	**2.7**	0.1	- 0.7	~ **0.0**
Total	3,500	5,300	4,400	2,671	4,657	3,501	829	643	899
no./mile >	4.2	6.4	**5.3**	3.2	5.6	**4.2**	1.0	0.8	**1.1**

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APPENDIX B

Use of Sterile Sport Fishes (Triploid/Hybrid) Stocked in the Upper Colorado River Basin

Per the Procedures for Stocking Nonnative Fish Species in the Upper Colorado River Basin (Stocking Procedures; USFWS 2009) to consider use of utilize sterile (hybrid/triploid) fishes to help control nonnative fish species, the information herein provides a brief review of the status of these technologies for various sport fishes. Many of these species and some of the hybrids are present or have been discussed for sport fish management in the upper Colorado River basin (UCRB). The use of sterile hybrids (e.g., tiger muskie) or sterile triploids (e.g., grass carp) may help restrict spread of these species in watersheds (Carlson and Daniels 2004). The stocking of approved sterile fish species in specific location equipped with screens or otherwise managed to prevent fish escapement would provide redundancy and a more preventive strategy to control the access of these nonnative fish species to critical habitat for endangered fishes. Further, illegal transfers of sterile fish may help limit an expansion of overall propagule pressure and the invasive capacity of those sport fishes that have proven problematic within critical habitat of the UCRB. Stocking reproductively sterile fish may be an ecologically risk-averse option compared to stocking diploid, fertile fish which may create problematic, self-sustaining populations (Budy et al. 2012).

Basic information on the use of hybrids and triploids in aquaculture and fisheries management is provided in Bartley et al. (2001) and Tiwary (2004). The information contained in this Appendix provides initial guidance based on available information concerning the fertility of hybrids, the utility of triploidy for specific species, and whether hybridization should be used in conjunction with triploidy to better promote sterility. Concern remains that the use of hybrids may functionally introduce new genetic material into the UCRB of unknown invasiveness should a hybrid prove fertile and backcrossing occurs. Similarly, induction of triploidy may not be 100% or the method of confirming triploidy may not be precise, risking the stocking of fertile individuals of a species of unknown invasive potential in the UCRB. Further, to provide and sustain quality sport fisheries, survival, fitness, and overall performance in hatchery and stocked environments should be evaluated (Kozfkay et al. 2006; Budy et al. 2012).

Salmonids (*Oncorhynchus*, *Salmo*, *Salvelinus*)

Sterility in triploid salmonids of both sexes and inhibition of sexual maturation in triploid females have been exploited in both commercial salmonid culture and fisheries management (Ihssen et al. 1990). Triploidy has been induced in many salmonid species by application of thermal or pressure shocks to newly fertilized eggs (Galbreath and Samples 2000). While salmonids are generally considered to be compatible with endangered fish recovery in the UCRB, techniques to induce sterility to control population expansion of salmonids are available, achieving induction rates of 75-100% (Budy et al. 2012), but often exceeding 95% (96.2%, Kozfkay, et al. 2006; 98%, Koenig et al., 2011, 95%, Koenig and Meyer 2011).

Channel catfish *Ictalurus punctatus* and catfish hybrids *I. punctatus* x *I.* spp.

Channel catfish x blue catfish *I. furcatus* hybrids are fertile and offer desirable characteristics , but these F_1 hybrids do not readily reproduce and performance of F_2 individuals is inferior (Masser and Dunham 1998; Dunham and Argue 2000). Triploid induction of channel catfish is feasible (Wolters et al. 1982; Chrisman et al. 1983), but the collection of large numbers of fertilized eggs may have limited its widespread application (Tucker and Hargreaves 2004).

Northern pike *Esox lucius* and tiger muskie *E. lucius* x *E. masquinongy*

Hybrid tiger muskie are generally considered to be functionally sterile (Wahl and Stein 1993; Bartley et al. 2004). While induction of triploidy in northern pike is feasible (Luczynski and Woznicki 1995; Kucharczyk et al. 1999), the technique has not been widely applied (UDWR 2010). The induction of triploidy in tiger muskie is apparently unreported, but has been proposed to further ensure that hybridization between tiger muskie and native muskellunge cannot occur.

Striped bass *Morone saxatilis* and palmetto bass (wiper) *M. saxatilis* x white bass *M. chrysops*

Hybrid wipers are fertile (Harrell 1984, Hodson 1989), but this capacity to reproduce appears to be mostly as concern where genetic introgression with striped bass or white bass in their native range is a concern (Harrell 1997; Kerby et al. 2002). Typically, wipers must be artificially produced and stocked regularly to sustain populations in impoundments (Nelson et al. 2008). There is no evidence of recruiting populations of hybrid striped bass in a naturalized setting that have resulted from continued hybridization with other hybrids or either parent species. Although F-2 hybrids have been found in the wild (one *confirmed* in Avise and Van Den Avyle 1984), at best their reproductive success is marginal and morphology and growth rates of the resulting offspring are highly variable. Induction of triploidy in striped bass and its hybrids is feasible (Hallerman 1994), but does not appear to be widely applied (Harrell 1997; Kerby et al. 2002; Nelson et al. 2008).

Centrarchid sunfish (*Lepomis* spp. and *Pomoxis* spp) and their hybrids

Hybrid centrarchid sunfishes of the genera *Lepomis* (e.g., bluegill *L. macrochirus*) and *Pomoxis* (e.g., black crappie *P. nigromaculatus*) are fertile, although they display reduced reproductive capacity (Wills et al. 1994; Parsons and Meals 1997). Hybrids are often raised by sunfish hatcheries and they are popular for stocking private ponds (Bolnick 2009). Induction of triploidy is feasible for both genera and their hybrids (Baldwin et al. 1990; Wills et al. 1994; Parsons and Meals 1997; Wills et al. 2000), and may reinforce the partial sterility of hybrids (Bolnick 2009), but the technique does not appear to be widely applied (Arslan and Phelps 2004; Wang et al. 2008).

Black bass *Micropterus* spp. and their hybrid

Natural hybridization by largemouth bass *Micropterus salmoides* and smallmouth bass *M. dolomieu* is rare (Barthel et al. 2010). Artificial hybridization of these species has been performed, to produce the "mean- mouth" hybrid, which is fertile, and has the ability to backcross with the parent species, thus this hybrid has not been considered for use in fisheries management (Becker 1983). Induction of triploidy has been performed in largemouth bass (Neal et al. 2004), but the technique is hampered by the significant environmental and behavioral stimuli associated with final maturation and availability of eggs (Neal and Noble 2008). It does not appear that efforts to induce triploidy in smallmouth bass have been reported.

Walleye *Sander vitreus* and saugeye (*S. vitreus* x sauger *S. canadensis*)

Hybrid saugeye are not sterile and have been documented to reproduce with other saugeyes or with walleyes (Fiss et al. 1997, White et al. 2005). It is often recommended that saugeye not be stocked in waters which contain native walleye or sauger populations or in walleye or sauger brood sources which sustain hatchery and stocking programs for these species. Such policies attest to the fertility of saugeye and are intended to prevent interbreeding and preserve the genetic integrity of native percids or percid broodstocks (Garcia-Abiado et al. 2002; Quist and Guy 2004; White 2005). Induction and testing of triploidy has been performed in walleye (Ewing et al. 1991; Kebus 1996) and triploid walleyes have been produced and considered for stocking in reservoirs to prevent hybridization with native saugeye (Henckel 2009). Hydrostatic shock of walleye or saugeye eggs may yield triploid induction rates ranging from 90% to 100% (Malison and Garcia-Abiado 1996; Garcia-Abiado et al. 2001; Malison et al. 2001), with 100% triploidy in saugeye apparently being provided by use of a 2.7L vs. 1.0 L pressure chamber (Abiado et al. 2007).

Table B-1. Comparison of the use of hybridization and/or the induction of triploidy in warmwater fish species occurring or proposed for introduction in the upper Colorado River basin (UCRB).

Species or hybrid	Hybrid fertile?	Triploid induction commonly applied?	Triploidy commonly advised to ensure hybrid sterility?	Notes
Salmonids	Some fertile	Yes	Yes, triploidy used to control reproduction & hybridization	Triploidy techniques for salmonids well developed & widely applied
Tiger trout, splake, etc.		No		
Channel catfish (CCF)	Yes	Yes	No - triploidy may be used to improve commercial growth	Hybrid not recommended for UCRB; consider triploidy for CCF?
Channel x blue catfish hybrid		Yes		
Northern pike	No	No	No - may be used minimize hybridization with muskellunge	Tiger muskie previously approved for stocking in UCRB reservoirs
Hybrid tiger muskie		No		
Moronids (striped bass=STB)	Yes (see discussion on pg 82)	No	No – used to prevent hybridization with native striped or white bass	STB in L. Powell; three individuals collected in the lower Colorado River (n=1 in 2012; n=2 in 2013). At the 2013 NNF Workshop, Upper Basin researchers reviewed information provided by UDWR in support of including wiper on the Compatible list. Risk was determined low enough to include on the list, but use of this hybrid should be evaluated on a case by case basis.
Hybrid palmetto bass (wiper)		No		
Centrarchid sunfish	Yes	No	No – being researched/developed to maximize commercial growth	Do not introduce new species or hybrids into UCRB
Centrarchid sunfish hybrids		No		
Black bass	Yes	No	No – reproductive/ environmental cues & behavior limit application	Do not allow hybrids in UCRB; triploidy insufficiently developed
Black bass hybrids		No		
Walleye	Yes	Yes	Yes – used to limit reproduction and hybridization with walleye	Only consider/allow stocking of triploid walleye/saugeye in UCRB
Hybrid saugeye		Yes		

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APPENDIX C

Proposed Lists of Nonnative Aquatic and Riparian Species that are Considered Compatible or Non-Compatible with Endangered Fish Recovery in the Upper Colorado River Basin

Table C-1. Preliminary list of nonnative aquatic species compatible with recovery/preservation of endangered/native, nonsalmonid aquatic species within critical habitat of the upper Colorado River basin (UCRB). Judicious management of compatible species must conform to Stocking Procedures (2009*) which prohibits stocking directly into riverine critical habitat and requires that nonsalmonid species be managed in isolated or screened ponds or reservoirs to prevent/control their escapement into critical habitat. Non-compatible species should not be further introduced or stocked into any waters in the UCRB.

COMPATIBLE list	NON-COMPATIBLE list
Fish	
Kokanee *Oncorhynchus nerka* Rainbow trout *Oncorhynchus mykiss* Brown trout *Salmo trutta* Brook trout *Salvelinus fontinalis* Lake trout *Salvelinus namaycush* Arctic char *Salvelinus arcticus* Tiger muskie *Esox lucius* x *E. maquinongy* Bluegill *Lepomis macrochirus* Black crappie *Pomoxis nigromaculatus* Largemouth bass *Micropterus salmoides* Palmetto bass (wiper) *M. saxatilis* x white bass *M. chrysops* Yellow perch *Perca flavescens* Triploid grass carp *Ctenopharyngodon idella* Fathead minnow *Pimephales promelas*	Smallmouth bass *Micropterus dolomieu* Northern pike *Esox lucius* Walleye *Sander vitreus* White sucker *Catostomus commersoni* Red shiner *Cyprinella lutrensis* Burbot *Lota lota* Flathead catfish *Pylodictis olivaris*
Crustaceans	
	All crayfish species
	Anchor worm *Lernaea cyprinacea*
Molluscs	
	Drissena spp.
	New Zealand mud snail *Potamopyrgus antipodarum*
Cestodes	
	Asian tapeworm *Bothriocephalus acheilognathi*
Plants	
	Tamarisk *Tamarix* spp.,
	Russian olive *Elaeagnus angustifolia*
	Didymo *Didymosphenia geminata*

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APPENDIX D

The Introduction and Spread of Gizzard Shad *Dorsoma cepedianum* in the Upper Colorado River Basin

Gizzard shad *Dorsoma cepedianum* are believed to have been introduced in the Colorado River basin in 1996 by accidental stocking into Morgan Lake, which is located along the San Juan River near Farmington, New Mexico (Finney and Fuller 2008). Gizzard shad in Morgan Lake likely originated from a shipment of largemouth bass from Inks Dam National Fish Hatchery in Texas (Mueller and Brooks 2004. Inspection of subsequent shipments from this hatchery found nine additional, unintentional fish species (Mueller and Brooks 2004).

Gizzard shad, first detected in the San Juan River just upstream of Lake Powell in Utah-Arizona in 2000 (Mueller and Brooks 2004), spread throughout the entire reservoir by 2004 (Vatland and Budy 2007). They were detected in the Gunnison River at the Redlands Fish Ladder in Colorado by 2006 and by 2007, gizzard shad were detected near the confluence of the Green and Yampa rivers in Dinosaur National Monument (Finney and Fuller 2008). The gizzard shad is considered a facultative riverine species that proliferates in reservoirs and then moves upstream in large numbers (Winston et al. 1991).

While gizzard shad were projected to have limited impact on the striped bass *Morone saxatilis*-threadfin shad *D. petenense* predator-prey cycle in Lake Powell (Vatland and Budy 2007), concern remains about their capacity to impact these species and the overall fishery (Vatland et al. 2008). Similarly, the potential impact by gizzard shad to the riverine food web in the upper Colorado River basin (UCRB) remains unknown. The planktovorous and benthivorous food habits of gizzard shad and their disturbance of sediments can alter food supplies for other fishes (Devries and Stein 1992, Gido 2003). Gizzard shad move into and exploit food resources in floodplain habitats (Zueg et al. 2009), which are important nursery habitats for razorback sucker *Xyrauchen texanus*.

The movement and feeding behavior of gizzard shad causes concern about their potential impact to the water conditions and food supplies in backwater habitats of young-of-year and juvenile native and endangered fishes in the UCRB. Skorupski et al. (2012) reported gizzard shad in backwaters of the middle Green River in Utah. The capacity of gizzard shad to alter food webs is well known (DeVries and Stein 1992; Vanni et al. 2005) and may include enhancing the prey base for nonnative piscivores such as smallmouth bass *Micropterus dolomieu* and walleye *Sander vitreus* (Wuellner et al. 2010) in the UCRB.

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APPENDIX E

HACCP Example: Wyoming Game & Fish Proposal to transplant roundtail chub to Scab Lake June 3, 2009

Background Information

Roundtail chub are native to the Green River and its tributaries (including the Little Snake River drainage) within Wyoming (Baxter and Stone 1995). This species is most often found in deep, slow pools with hiding cover in rivers and streams (Bezzerides and Bestgen 2002). In Wyoming, they can be found in large rivers (e.g., Green River), but they also inhabit small headwater streams (e.g., Muddy Creek south of Rawlins) and several lakes near Pinedale, Wyoming (Wyoming Game and Fish Department, fisheries databases). Very few lentic populations of roundtail chub have been documented outside of the upper Green River basin, and lotic populations tend to disappear soon after impoundment in new reservoirs (Bezzerides and Bestgen 2002).

The distinct population segment of roundtail chub located below Glen Canyon Dam has been petitioned for listing under the Endangered Species Act (Center for Biological Diversity 2003). Within Wyoming this species is categorized as a Status 1 Native Species (NSS1), meaning that populations are physically isolated and/or exist at extremely low densities throughout their range, habitats are declining or vulnerable, and extirpation appears possible (Wyoming Game and Fish Department 2005). Recent surveys (Wyoming Game and Fish Department, fisheries databases; Wheeler 1997; Gill et al. 2004; Gill et al. 2005) show that the current distribution of roundtail chub in the Green River drainage is limited and fish numbers are low. Gelwicks (2009) noted that the distribution of roundtail chub in Wyoming's portion of the Green River drainage has contracted considerably in the last five decades.

Introduced species are probably the most serious threat to long-term persistence of the lentic populations of roundtail chub found in the upper Green River basin. Predation by introduced piscivorous fish species (e.g., brown trout, lake trout, rainbow trout) is probably the biggest threat to these populations. Depending on the species involved, competition for food or space, and other mechanisms, such as parasites or disease transmission, can also be important factors.

Several of the known lentic populations of roundtail chub contain very few individuals (e.g., New Fork Lake, Willow, and Fremont Lakes), and other populations (e.g., Boulder Lake) appear to have been extirpated within the last few decades (Wyoming Game and Fish Department, Lakestn database). In addition, all of the remaining lentic populations in the upper Green River basin coexist with large numbers of introduced piscivorous fish species (notably lake trout and brown trout), so they are likely under considerable predation pressure. Given that it is not logistically or socially feasible to remove the introduced predaceous fish species, it would be prudent to develop one or more refuge populations of lentic roundtail chub in areas without predaceous fish species as a means to safeguard this genetic line from potential demise.

Approach

Roundtail chubs will be captured with trap nets in Little Halfmoon and/or Halfmoon Lake. These lakes are only approximately 0.25 miles apart, and are connected by a large stream. Suckers have been documented to move between these lakes, so it is likely that roundtail chubs also move between these waters. Therefore, it is reasonable to assume that the populations in these two lakes are panmictic, so mixing fish from both waters should not be problematic.

Roundtail chubs will be captured in late July or August 2009, beginning one week prior to the date when a helicopter will be available to transport the fish to Scab Lake. Eight hours of helicopter time has been included in the FY10 budget, which should be sufficient for one or two trips between Halfmoon Lake and Scab Lake (including shuttle time between the helicopter's home base and Halfmoon Lake). All fish captured will be identified to species, measured, and weighed. Roundtail chub larger than 7 inches and non-target species will be released to the lake where they were captured. Smaller roundtail chubs will individually inspected for parasites, fungal infections, and other maladies, as recommended by Dave Money, Fish Pathologist. Those that appear to be in good health and free of parasites, fungus, bacteria, and viruses will be placed in a livecar and held until translocation. Others will be returned to the lake where they were captured.

At least 100, but not more than 500, roundtail chubs will be moved to Scab Lake. This number could be captured in one week, based on catch rates recorded in previous years. However, if fewer than 100 roundtail chubs of the target size are captured in this timeframe, then an additional transplant will be done in 2010 (and possibly another in 2011) in order to assure that a sufficient number of individuals are available to avoid genetic problems in the new population. Fish will be moved from the livecar to the helicopter for transportation to Scab Lake, and then dropped into the lake from the air. Additional measures will be taken to reduce the possibility of moving non-target organisms. Details of these actions can be found in a separate Hazard Analysis and Critical Control Point Form and a Fish Transplant Request Form.

Scab Lake will be visually checked within 36 hours of stocking to determine if any fish died during transportation. Nets will be set in Scab Lake one year after at least 100 roundtail chubs have been move to determine if some fish have survived through the winter. If survival is documented at that time, nets will be set again two or three years later to determine if successful reproduction has occurred. Lessons learned from this transplant will be used to help define additional potential sites for establishment of refuge populations and refine techniques needed for successful translocations.

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WYOMING Fish Transplant Request

Who will have primary responsibility for this project? ***Pete Cavalli***
Description of what you would like to move: Roundtail chub
Why do you want to move these fish? ***To establish another self-sustaining RTC population in the upper Green River drainage***
Where is the source for these organisms? (be specific and include UTM and WaterID if possible): ***Little Halfmoon Lake (12T 605360E 4750961N) and/or Halfmoon Lake (12T 604980E 4753559N)***
Where do you want to transplant these organisms? (be specific and include UTM and WaterID if possible): ***Scab Lake (12T 623649E 4740180N)***

How far will the organisms be moved? Are there barriers?

	Transplant in small watershed (< 10 miles) without barriers (continuous, streams within drainage)·
	Transplant in small watershed (< 10 miles) with barriers (barriers between streams within drainage)
	Transplant in tributary with barriers or body of water is totally isolated (non-continuous)
x	Transplant within river basin
	Transplant out of river basin
	Comments:

Habitat differences between source location and transplant destination

	Like habitat
x	Known difference in habitat from source to destination·
	Comments: ***source lakes are deeper and have large flowing inlets compared to destination lake***

Differences in species assemblages between source location and transplant destination

	No differences in known species assemblages
x	Known difference in species assemblages, but not a concern
	Known difference in species assemblages, and a concern
	Comments***: the destination lake was selected because it is free of piscivorous fish***

Presence of non-target species that could be a problem

	No non-target species in the source
x	Potential of nts in source, but not a concern
	Potential of nts in source and a concern
	Comments: ***the non-target species are already widespread in the drainage***

Aquatic Nuisance Species (ANS)

	No known ANS in source
x	ANS in the source,
	ANS present in tributary, but not identified in source
	ANS present in source, but controllable
	ANS present in source and a concern
	Comments: ***several species on non-native trout, minnows, and suckers***

Optical Recognition is Virtually Impossible (ORVI) organisms

x	No known ORVI present in source
	ORVI present, but not a concern
	ORVI present, but controllable in source
	ORVI in source
	Comments:

Use the above evaluation to complete the "Risk Assessment Matrix (RAM) For Aquatic Importation And Transplant". What is the risk level?

Level 8, but ANS can be removed following procedures outlined in the project plan, thus reducing the threat to an acceptable level

HACCP Step 1 – Activity Description

Activity Description	
Facility:	**Site:** Halfmoon, Little Halfmoon, and Scab Lakes
Project Coordinator: Pete Cavalli **Site Manager:** Pete Cavalli **Address:** WY Game and Fish Dept., PO Box 850, Pinedale, WY 82941 **Phone:** 307 367-4353	**Activity/Management Objective:** Collect genetically pure roundtail chub (RTC) from Little Halfmoon and Halfmoon Lakes for transplant to Scab Lake to establish another self-sustaining RTC population in the upper Green River drainage.
Project Description: i.e. Who; What; Where; When; How; Why	
Who: FMPE **What:** Transplant roundtail chub (RTC) from Halfmoon & Little Halfmoon Lakes to Scab Lake. **Where:** Halfmoon and Little Halfmoon Lakes (Pole Creek drainage) and Scab Lake (East Fork drainage) are in the Green River basin. **When:** July/August 2009; additional work may occur in 2010 and 2011, if enough fish are not caught in 2009 **How:** Collect RTC from Halfmoon and/or Little Halfmoon Lakes using trap nets. Transfer to stocking tank for transport to a suitable helicopter-landing site. Using a helicopter, transport fish to Scab Lake for release. **Why:** Establish another genetically pure RTC population in the Green River drainage	

HACCP Step 2 – Identify Potential Hazards

(to be transferred to column 2 of HACCP Step 4 – Hazard Analysis Worksheet)

Hazards: Species or Contaminants Which May Potentially Be Moved/Introduced
Vertebrates: Lake trout, brown trout, brook trout, rainbow trout, cutthroat trout, mottled sculpin, mountain whitefish, flannelmouth sucker, white sucker, mountain sucker, hybrid suckers, speckled dace, redside shiner, northern leopard frog, tiger salamander, boreal chorus frog, wandering garter snake
Invertebrates: aquatic insects, zooplankton (including Mysis), mollusks, oligocheates, and possibly crayfish
Plants: various species of algae and aquatic macrophytes, upland vegetation seeds
Other Biologics (e.g., genetics, disease, pathogen, parasite, or non-pathogens: Chytrid fungus, whirling disease, furunculosis, and other parasites and pathogens may be present. Ligula is the only known species present in Little Halfmoon Lake, but Chytrid, whirling disease, and furunculosis are known from other waters in the drainage.
Others (non-biological contaminants e.g., pesticide residue, oil products, etc. or harborage via packing or construction materials, etc.): None

HACCP Step 3 – Flow Diagram

Flow Diagram Outlining Sequential Tasks to Complete Activity/Project
Described in HACCP Step 1 – Activity Description (to be transferred
To column 1 of the HACCP Step 4 – Hazard Analysis Worksheet)

Task 1	Capture fish with trap nets. Sort RTC from non-target organisms, and return all non-target species to the source water. Also return all RTC >7 inches total length and those that have obvious parasites or pathogens to the source water.Place RTC suitable for translocation in a livecar held in the source water until at least 100 RTC are available for translocation.

⇓

Task 2	Fill disinfected stocking tank with municipal water at the Pinedale Regional Office 24 hours prior to translocation. Aerate and add ice to cool water, if necessary.

⇓

Task 3	Net fish from livecar and visually inspect each individual for parasites or pathogens. Release all non-target organisms and RTC with obvious parasites or pathogens to the source water, and place suitable candidates for transplantation in stocking tank. Transport RTC in stocking tank to an appropriate site for transfer to a helicopter.

⇓

Task 4	Fill stocking device on helicopter with city water (what would be the source of this water?) and RTC from stocking tank. Dump excess water from fishless stocking tank in uplands away from ephemeral and perennial drainages.

⇓

Task 5	Use helicopter to transport RTC to Scab Lake and release fish from air.

⇓

Task 6	Disinfect all gear that was in contact with fish or water.

HACCP Step 4 – Hazard Analysis Worksheet

1 Tasks (from HACCP Step 3 - Flow Diagram)	**2** Potential hazards identified in HACCP Step 2	**3** Are any potential hazards significant? (yes/no)	**4** Justify evaluation for column 3	**5** What control measures can be applied to prevent undesirable results?	**6** Is this task a critical control point? (yes/no)
Task 1: Capture fish with trap nets. Sort RTC from non-target organisms, and return all non-target species to the source water. Also return all RTC >150mm total length and those that have obvious parasites or pathogens to the source water. Place RTC suitable for translocation in a livecar held in the source water until at least 100 RTC are available for translocation.	Vertebrates: lake trout, brown trout, brook trout, rainbow trout, cutthroat trout, mottled sculpin, mountain whitefish, flannelmouth sucker, white sucker, mountain sucker, hybrid suckers, speckled dace, redside shiner, northern leopard frog, tiger salamander, boreal chorus frog, wandering garter snake	No	All fish will be individually handled before transport so any non-target organism can be removed at that time.	All captured fish will be examined. RTC will be held in live-cars, and non-target vertebrates will be returned to the source water.	No
	Invertebrates: aquatic insects, zooplankton (including Mysis), worms, and possibly crayfish	No	All fish will be individually handled before transport so any non-target organism can be removed at that time.	All non-target invertebrates will be returned to the water.	No
	Plants: various species of algae and aquatic macrophytes, upland vegetation seeds	No	All fish will be individually handled before transport so any non-target organism can be removed at that time.	All non-target plants will be returned to the water.	No
	Other Biologics: parasites, pathogens	No	All fish will be individually handled before transport so any non-target organism can be removed at that time.	Follow visual inspection protocol as outlined by certified fisheries pathologist and return any potentially infected RTC to the source water.	No
	Others: None	No			

HACCP Step 4 – Hazard Analysis Worksheet (continued)

1 Tasks (from HACCP Step 3 - Flow Diagram)	**2** Potential hazards identified in HACCP Step 2	**3** Are any potential hazards significant? (yes/no)	**4** Justify evaluation for column 3	**5** What control measures can be applied to prevent undesirable results?	**6** Is this task a critical control point? (yes/no)
Task 2: Fill disinfected stocking tank with municipal water at the Pinedale Regional Office 24 hours prior to translocation. Aerate and add ice to cool water, if necessary.	Vertebrates: lake trout, brown trout, brook trout, rainbow trout, cutthroat trout, mottled sculpin, mountain whitefish, flannelmouth sucker, white sucker, mountain sucker, hybrid suckers, speckled dace, redside shiner, northern leopard frog, tiger salamander, boreal chorus frog, wandering garter snake	No	No non-target species present.		
	Invertebrates: aquatic insects, zooplankton (including Mysis), worms, and possibly crayfish	No	No non-target species present.		
	Plants: various species of algae and aquatic macrophytes, upland vegetation seeds	No	No non-target species present.		
	Other Biologics: parasites, pathogens	No	No non-target species present.		
	Others: None	No	No non-target species present.		

HACCP Step 4 – Hazard Analysis Worksheet (continued)

1 Tasks (from HACCP Step 3 - Flow Diagram)	**2** Potential hazards identified in HACCP Step 2	**3** Are any potential hazards significant? (yes/no)	**4** Justify evaluation for column 3	**5** What control measures can be applied to prevent undesirable results?	**6** Is this task a critical control point? (yes/no)
Task 3: Net fish from livecar and visually inspect each individual for parasites or pathogens. Release all non-target organisms and RTC with obvious parasites or pathogens to the source water, and place suitable candidates for transplantation in stocking tank. Transport RTC in stocking tank to an appropriate site for transfer to a helicopter.	Vertebrates: lake trout, brown trout, brook trout, rainbow trout, cutthroat trout, mottled sculpin, mountain whitefish, flannelmouth sucker, white sucker, mountain sucker, hybrid suckers, speckled dace, redside shiner, northern leopard frog, tiger salamander, boreal chorus frog, wandering garter snake	Yes	Non-target vertebrates may have entered livecar while it was in the lake.	All captured fish will be examined. RTC will be placed in stocking tank and non-target vertebrates will be returned to the source water.	Yes
	Invertebrates: aquatic insects, zooplankton (including Mysis), worms, and possibly crayfish	Yes	Zooplankton and small insects may be present in the livecar in the lake.	Handle each fish individually to check for non-target invertebrates and transfer RTC to stocking tank. Non-target invertebrates will be returned to the source water.	Yes
	Plants: various species of algae and aquatic macrophytes, upland vegetation seeds	Yes	Plant fragments and algae may be present in the livecar in the lake.	Handle each fish individually to check for non-target plants and transfer RTC to stocking tank. Non-target plants will be returned to the source water.	Yes
	Other Biologics: parasites, pathogens	Yes	Parasites and pathogens may infect fish in the livecar in the lake.	Handle each fish individually to check for non-target parasites and transfer RTC to stocking tank. RTC infested with parasites or pathogens will be returned to the source water.	Yes
	Others: None				

HACCP Step 4 – Hazard Analysis Worksheet (continued)

1 Tasks (from HACCP Step 3 - Flow Diagram)	**2** Potential hazards identified in HACCP Step 2	**3** Are any potential hazards significant? (yes/no)	**4** Justify evaluation for column 3	**5** What control measures can be applied to prevent undesirable results?	**6** Is this task a critical control point? (yes/no)
Task 4: Fill stocking device on helicopter with water and RTC from stocking tank. Dump excess water from fishless stocking tank in uplands away from ephemeral and perennial drainages.	Vertebrates: lake trout, brown trout, brook trout, rainbow trout, cutthroat trout, mottled sculpin, mountain whitefish, flannelmouth sucker, white sucker, mountain sucker, hybrid suckers, speckled dace, redside shiner, northern leopard frog, tiger salamander, boreal chorus frog, wandering garter snake	No	Hazards were removed in Task 3.		
	Invertebrates: aquatic insects, zooplankton (including Mysis), worms, and possibly crayfish	Yes	Zooplankton and small insects may be present water moved with fish.	Use large mesh net to filter non-target invertebrates and transfer RTC to helicopter. Dump stocking tank water in uplands away from ephemeral and perennial drainages.	Yes
	Plants: various species of algae and aquatic macrophytes, upland vegetation seeds	No	Plant fragments and algae may be present in water moved with fish.	Use large mesh net to filter non-target plants and transfer RTC to helicopter. Dump stocking tank water in uplands away from ephemeral and perennial drainages.	Yes
	Other Biologics: parasites, pathogens	No	Addressed in Task 3.		
	Others: None				

HACCP Step 4 – Hazard Analysis Worksheet (continued)

1 Tasks (from HACCP Step 3 - Flow Diagram)	**2** Potential hazards identified in HACCP Step 2	**3** Are any potential hazards significant? (yes/no)	**4** Justify evaluation for column 3	**5** What control measures can be applied to prevent undesirable results?	**6** Is this task a critical control point? (yes/no)
Task 5: Use helicopter to transport RTC to Scab Lake and release fish from air.	Vertebrates: lake trout, brown trout, brook trout, rainbow trout, cutthroat trout, mottled sculpin, mountain whitefish, flannelmouth sucker, white sucker, mountain sucker, hybrid suckers, speckled dace, redside shiner, northern leopard frog, tiger salamander, boreal chorus frog, wandering garter snake	No	Hazards were removed in Task 3.		
	Invertebrates: aquatic insects, zooplankton (including Mysis), worms, and possibly crayfish	No	Hazards were removed in Tasks 3 and 4.		
	Plants: various species of algae and aquatic macrophytes, upland vegetation seeds	No	Hazards were removed in Tasks 3 and 4.		
	Other Biologics: parasites, pathogens	No	Addressed in Task 3.		
	Others: None				

HACCP Step 4 – Hazard Analysis Worksheet (continued)

1 Tasks (from HACCP Step 3 - Flow Diagram)	**2** Potential hazards identified in HACCP Step 2	**3** Are any potential hazards significant? (yes/no)	**4** Justify evaluation for column 3	**5** What control measures can be applied to prevent undesirable results?	**6** Is this task a critical control point? (yes/no)
Task 6: Disinfect all gear that was in contact with fish or water.	Vertebrates: lake trout, brown trout, brook trout, rainbow trout, cutthroat trout, mottled sculpin, mountain whitefish, flannelmouth sucker, white sucker, mountain sucker, hybrid suckers, speckled dace, redside shiner, northern leopard frog, tiger salamander, boreal chorus frog, wandering garter snake	No	Hazards were removed in Task 3.		
	Invertebrates: aquatic insects, zooplankton (including Mysis), worms, and possibly crayfish	Yes	Eggs or other early life stages may be present in residual water or attached to equipment.	Disinfect all gear used in water with a chlorine bleach solution or other disinfectant.	Yes
	Plants: various species of algae and aquatic macrophytes, upland vegetation seeds	Yes	Seeds, microscopic algae, and plant fragments could be present on equipment	Disinfect all gear used in water with a chlorine bleach solution or other disinfectant.	Yes
	Other Biologics: parasites, pathogens	Yes	Bacteria, viruses, and early life stages of parasites could be present in residual water or attached to equipment.	Disinfect all gear used in water with a chlorine bleach solution or other disinfectant.	Yes
	Others: None				

HACCP Step 5 – HACCP Plan Form

HACCP Plan Form (all CCP's or "yes's" from column 6 of HACCP Step 4 – Hazard Analysis Worksheet)		
(1) Critical Control Point:		Task 3: Capture RTC with trap nets. Sort RTC and non-target species. Return all non-target species and RTC infected with parasites or pathogens to the source water.
Significant Hazard(s):		Introduction of non-target species to Scab Lake.
Limits for Each Control Measure:		Zero non-target vertebrates, invertebrates, and plants moved to Scab Lake. Parasites and pathogens to level detectable by visual examination.
Monitoring	**What:**	Sort all fish captured in trap nets.
	How:	Visual examination procedure specified by fish pathologist.
	Frequency:	Individual fish
	Who:	FMPE
Evaluation & Corrective Action(s) (if needed):		Place only healthy RTC in stocking tank; resort if possible contamination is observed.
Supporting Documents (if any):		Stocking slip and recommendations from fish pathologist
(2) Critical Control Point:		Task 4: Dump excess water from fishless stocking tank in uplands away from ephemeral and perennial drainages.
Significant Hazard(s):		Introduction of invertebrates, plants, or other biologics (pathogens or parasites) into other waters.
Limits for Each Control Measure:		Zero non-target vertebrates, invertebrates, plants, and parasites and pathogens moved to other waters.
Monitoring	**What:**	Stocking tank water.
	How:	Dump water in uplands away from all waterways.
	Frequency:	After fish are removed from stocking tank.
	Who:	FMPE
Evaluation & Corrective Action(s) (if needed):		Make sure no standing water remains in tank after draining. Dry with towel or sponge, if necessary.
Supporting Documents (if any):		none
(3) Critical Control Point:		Task 6. Disinfect all gear that was in contact with fish or water.
Significant Hazard(s):		Introduction of invertebrates, plants, parasites, or pathogens into other waters.
Limits for Each Control Measure:		Zero non-target invertebrates, plants, parasites and pathogens moved to other waters.
Monitoring	**What:**	All gear used in transplant project.
	How:	Disinfect all gear with chlorine bleach solution or other appropriate disinfectant.
	Frequency:	Before gear is used at another water.
	Who:	FMPE and helicopter contractor.
Evaluation & Corrective Action(s) (if needed):		Ensure all surfaces are in contact with disinfectant for appropriate amount of time. Disinfect a second time if deemed necessary.
Supporting Documents (if any):		WY Fisheries Management Protocol for Whirling Disease

Facility:	**Activity/Management Objective:** Establish a new population of roundtail chub in the upper Green River drainage.
Address:	
Signature: HACCP Plan was followed.	**Date:**

APPENDIX F

Recommended Electrofishing Guidelines for Upper Colorado River Basin Habitats Containing Endangered Fishes (2012)

Patrick J. Martinez and A. Lawrence Kolz

Introduction

Electrofishing fleet standardization requires: 1) electrodes to be of identical size and configuration to ensure nearly identical electrical resistance; 2) electrofishers that produce the same pulsed direct current (PDC) electrical waveform; and 3) ancillary electrofishing equipment (e.g., dip net size and mesh) and operations (e.g., net, number of netters, netter experience, etc.) that are similar (Martinez and Kolz 2009; Miranda 2009). The electrofishing fleet of the Upper Colorado River Endangered Fish Recovery Program (hereinafter Recovery Program) includes aluminum jon-boats boats with electrically conductive hulls and inflatable whitewater rafts made of non-conductive material. Boats provide increased mobility and are typically used during higher flows when water conductivity for a particular river reach is lower. However, when electrofishing in whitewater reaches and low river flows, when water conductivity is often higher, rafts are preferred because of their maneuverability and inherent safety.

Recovery Program electrofishing boats are equipped with two anodic hemispheres suspended from forward projecting parallel booms while the smaller rafts are limited to a singular anodic hemisphere. This difference in anodes necessarily implies that the electrified volumes of water created by the boats produce a larger electrical fishing “net” than that of the rafts. However, it is possible to adjust the power output of the electrofishing units so that the actual in-water electroshocking effects on the fish are comparable between the boats and rafts.

The metal hull of the boats serves as the cathode and is therefore an inherent component to the system’s total electrode resistance: anodes plus cathodes. The nonconductive rafts must be fitted with dual cathodes, each consisting of multiple steel cables suspended from both sides of the rafts. These fundamental differences in the number of anodes and the relative size of the cathodes contribute to the difference in electrical system resistances between these two types of electrofishing crafts (Martinez and Kolz 2013).

Purpose

This sampling guide has been developed for the Recovery Program. These guidelines are intended to standardize electrode configurations and resistances for the Recovery Program’s electrofishing fleet consisting of aluminum-hulled jon-boats and whitewater rafts (Martinez and Kolz 2013). Further, these guidelines specify initial settings for the ETS 1D-72A electrofisher recommended for use in Recovery Program boats and rafts operating with standardized electrode configurations. These equipment and electrofisher setting consistencies are intended to provide the following benefits to those conducting or participating in Recovery Program projects or associated fish sampling activities in critical habitat:

1) Defensible scientific measurement to support intensive electrofishing as a safe, effective, and efficient method for the sampling and live-release of native and non-native fishes including sensitive (e.g., ESA-listed) species.

2) Simplified personnel training due to similar set-up of electrofishing boat and rafts, including standardized electrode resistances and a single boat-electrofisher model used in both crafts.

3) Enable crew member interchangeability and flexibility due to the similarity of boat and raft electrode configurations and increased familiarity with selection of boat-electrofisher settings.

4) Direct application of Power Transfer Theorem (Kolz 1989; Miranda and Dolan 2003) with calibrated peak-reading current and voltage meters supplied as standard equipment with the ETS 1D-72A electrofisher.

5) Expedited troubleshooting and interchangeability of faulty components among electrofishing craft due to similarities of boat and raft equipment.

6) Optimized purchase and compatible serviceability of electrofishing system components from vendors with potentially reduced costs to the Recovery Program.

Electrofishing Sampling Gear

Table 1 describes the recommended, standardized configurations and specifications for UCRB electrofishing boats and rafts. Figure 1 provides detailed specifications for ordering this boat electrofisher with the 72 amp, high output current option (MBS-1DPF-RLY-COS).

Figure 2 shows the slots cut into a 9-inch diameter stainless steel spherical anode to facilitate submergence or draining, and provides the vendor information for ordering spheres for uses as anodes. Figures 3 and 4 show the deployment of anodes from electrofishing boats and rafts, respectively. Figure 5 illustrates the design for the trailing cathodes required for use electrofishing whitewater rafts, which have non-conductive, synthetic hulls.

Table 2 provides a simplified method using a multiplier to convert specific conductivity to ambient conductivity. Figure 6 provides an electrofishing power chart to facilitate selection of initial peak power, voltage or current settings for different ambient water conductivities when using the ETS Electrofishing MBS 1D-72A boat-electrofisher in an electrofishing boat equipped with standardized electrodes per UCRB specifications. Figure 7 (*in progress as of January 2014*) provides an electrofishing power chart to facilitate selection of initial peak power, voltage or current settings for different ambient water conductivities when using the ETS Electrofishing MBS 1D-72A boat-electrofisher in an electrofishing raft equipped with standardized electrodes per UCRB specifications.

Table 3 provides the protocol for identifying and refining the fish threshold response to the initial peak power settings for boats and rafts. A field form for recording information about the electrofishing conditions, including water temperature, conductivity, and turbidity, electrofisher settings and output, and fish response is provided in Figure 8. Table 4 provides instructions for operation of the FLUKE 87V current meter and i100 current clamp if verification of current readings is necessary or desired.

Table 1. Recommended specifications and electrode configurations for electrofishing boats, rafts, and generators for use in the electrofishing fleet of the Upper Colorado River Endangered Fish Recovery Program and the San Juan Endangered Fish Recovery Implementation Program.

I. Electrofishing boat and raft specifications and maintenance:

A. Aluminum jon-boat 16-18 feet in length

1. Appropriately-sized outboard motor
    a. Propeller drive
    b. Jet drive
2. Anodes
    a. Two 9-inch diameter stainless steel spheres, 0.05-inch material thickness, with ½-inch FPT Hex-fitting for connecting ¼-diameter stainless steel cable to the anode, and ¼-inch slits cut vertically in sphere's quadrants (Figure 3) to facilitate submergence or draining
    b. One anode mounted on each boom and extended 90-inches from bow of boat at the waterline and spaced 80-inches apart
    c. Anodes deployed half-submerged when actively electrofishing
3. Cathode
    a. Aluminum jon boat hull
    b. Hull cleaned periodically to remove excessive debris, electrolysis deposits or anodizing (i.e., when electrical system resistance changes > 10%)
4. Boat electrical system resistance for standardized electrodes at 115 µS/cm (i.e., equal fish and water conductivities) ~ 66 ohms

B. Whitewater raft or cataraft14-16 feet in length (non-conductive synthetic hull)

1. Appropriate steering / propulsion capabilities for navigation
    a. Appropriately-sized and mounted oars
    b. Appropriately-sized outboard motor (propeller or jet drive)
2. Anode
    a. Single 9-inch diameter stainless steel sphere, 0.05-inch material thickness, with ½-inch FPT Hex-fitting for connecting ¼-diameter stainless steel cable to the anode, and ¼-inch slits cut vertically in sphere's quadrants (Figure 3) to facilitate submergence or draining
    b. Anode mounted on single boom and extended 55-inches from of hand-rail at bow of raft
    c. Anode deployed half-submerged when actively electrofishing
3. Cathode
    a. Two arrays of three stainless steel cables (¼-inch diameter), each strand 48-inches long (Figure 6), with one array trailing from each side of the raft 16-feet aft of the anode. The three cables are separated from one another by about 2-inches and are not to be bundled in a group.
    b. Replace frayed cathode cables.
4. Raft electrical system resistance for standardized electrodes at 115 µS/cm (i.e., equal fish and water conductivities) ~ 162 ohms

Table 1 (continued). Recommended specifications and electrode configurations for electrofishing boats, rafts, and generators for use in the electrofishing fleet of the Upper Colorado River Endangered Fish Recovery Program and the San Juan Endangered Fish Recovery Implementation Program.

II. Boat-electrofisher

- A. ETS Electrofishing, LLC, MBS 1D-72A boat-electrofisher
  1. Equipped with optional 72 amp, high output current
  2. Standard specifications have plugs and outlets placed on the right side of the boat-electrofisher box, but locating outlets and plugs in different locations should not affect interchangeability
  3. Detailed MBS 1D-72A boat-electrofisher specifications provided in Figure 3

- B. Boat-electrofisher operational criteria
  1. Pulsed direct-current (PDC)
  2. 20% duty cycle
  3. 60 Hz frequency (higher frequencies should be avoided to minimize injury to larger-size fusiform fishes - e.g., adult Colorado pikeminnow)

- C. Generator
  1. Capable of 5,500 W continuous
  2. Single phase
  3. 240 VAC output
  4. 60 Hz
  5. Generator MUST have a floating neutral (neutral ground broken), i.e., the neutral winding must NOT be connected to the generator frame - most generators of recent manufacture have a floating neutral
  6. Avoid generators that use "inverter" technology - generally these will have a small "i" in their model number. The electronics of inverter technology do not work well with capacitive loads such as those in boat-electrofishers

Table 2. Recommended specifications for "standard" ETS MBS 1D-72A electrofisher for use with electrofishing boats and rafts of the UCRB Endangered Fish Recovery Program.

ELECTROFISHING, LLC
3737 Eldorado Court
Verona, WI 53593
PH/FAX: 608-833-2088
Email: ets@etselectrofishing.com

Qty.	Description	Model/Type/Function
1	Boat electrofishing control box unit: 0-300/600 Vpeak dual range pulsed DC output)	5KW, MBS-1DPF-RLY-COS pulsed-DC. 240 VAC input via 14-3 SOOW, 8 ft. cable pig-tail from control box terminated in L14-30P plug compatible with Honda EM6500SXK generator. Pig-tail exits from RIGHT side of box. Standard WI-style 4 slot twist lock receptacle, Pass & Seymour 7410, or equivalent for high voltage output located on RIGHT side of box. 2 slots X & Y carry + voltage to booms. 2 slots W & Z carry – return from boat hull. 2-pin Amphenol receptacle 97-3102A-16-11P located on RIGHT side of box. 2 wires serve either safety pad or footswitch. No reset required at box…output power is disconnected only temporarily until pad or footswitch is stepped on again.
1	Add high output current option.	Increase maximum output peak DC pulsed current capability from 45 to **72 amps peak current maximum. Useful in high conductivity water.**
1	Add High Voltage relay-switched output	Adds a redundant high voltage relay to the output circuit that positively removes power to the booms when either the footswitch or safety pad is opened. (provides additional safety to operators on rafts) This is suffix "RLY"
1	Add footswitch/pad-control circuitry option to MBS box.	Allows turning on and off the high voltage from a remote location on the boat using a footswitch or pad without requiring a reset at box. Does not include the footswitch. This is suffix "P".
1	Add additional receptacle for separate footswitch connection.	Adds an additional 97-3102A-16-11P 2-pin Amphenol receptacle located on RIGHT side of box. 2 wires serve either safety pad or footswitch. No reset required at box…output power is disconnected only temporarily until pad or footswitch is stepped on again. Note: pad and footswitch are wired in series. This is suffix "F"
1	Add dummy interlock plug for lower footswitch/pad receptacle.	Adds a chained 2-pin dummy interlock plug 97-3106A-16-11S that can be plugged into the lower footswitch/pad receptacle when only one control device is needed (either pad or footswitch)
1	High voltage output plug	Standard WI-style 4-prong twist lock plug, Leviton 7411C or equivalent.
1	Safety pad plug with cable clamp	2-socket Amphenol plug 97-3106A-16-11S with cord clamp 97 -3057-1008-1.
1	Footswitch plug with cable clamp	2 socket Amphenol plug 97-3106A-16-11S with cord clamp 97-3057-1008-1.
1	Manual	
1	One year warranty, parts and labor	

Figure 3. A 9-inch (23 cm) diameter sphere (0.05-inch material thickness, with ½-inch FPT Hex-fitting for connecting ¼-inch diameter stainless steel cable to the anode) showing ¼-inch slits cut vertically (plasma cut) in sphere's quadrants to facilitate submergence or draining. Contact information for ordering the stainless steel spheres: Naugatuck Manufacturing Company, Inc., 105 Avenue of Industry, PO Box 3175, Waterbury, CT 06705, Telephone (203)754-2807, FAX (203755-1924, website http://www.naugatuckmfg.com/

Figure 4. Deployment of two spherical anodes from booms of UCRB Recovery Program electrofishing boat. One anode mounted on each boom and extended 90-inches from bow of boat at the waterline and spaced 80-inches apart. Anodes half-submerged when actively electrofishing

Figure 5. Deployment of single spherical anode from boom of UCRB Recovery Program electrofishing raft . Anode mounted on single boom and extended 55-inches from of hand-rail at bow of raft, and deployed half-submerged when actively electrofishing.

Figure 6. Configuration of trailing cable cathodes use UCRB Recovery Program electrofishing whitewater rafts. Two arrays of three stainless steel cables (¼-inch diameter), each strand 48-inches long, with one array trailing from each side of the raft 16-feet aft of the anode.

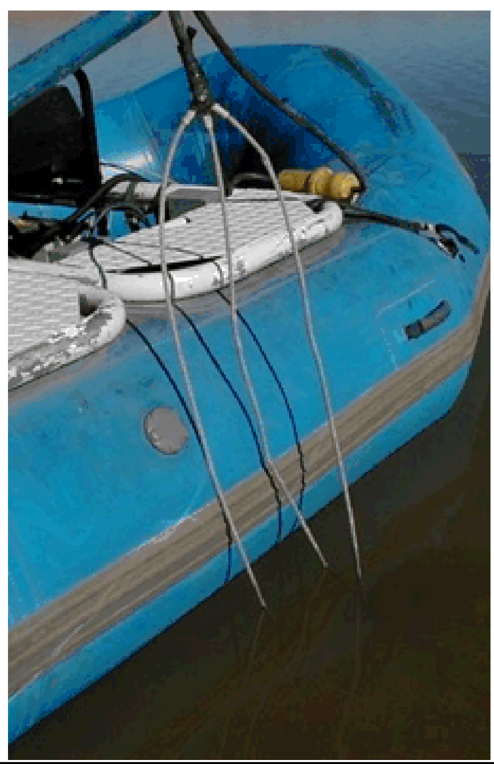


Table 2. Multiplier values for converting measurements of specific conductivity to ambient conductivity for water temperatures ranging from 0-30 ^{o}C:

Specific conductivity x Multiplier = Ambient conductivity

Specific to Ambient Conductivity Multipliers $C_a = C_s/1.02^{(Ts-Ta)}$, where T_s = 25 deg C	
T_a	**Multiplier**
30	1.104
29	1.082
28	1.061
27	1.040
26	1.020
25	1.000
24	0.980
23	0.961
22	0.942
21	0.924
20	0.906
19	0.888
18	0.871
17	0.853
16	0.837
15	0.820
14	0.804
13	0.788
12	0.773
11	0.758
10	0.743
9	0.728
8	0.714
7	0.700
6	0.686
5	0.673
4	0.660
3	0.647
2	0.634
1	0.622
0	0.610

Figure 6. Power chart with multiplier for constant power (M_{cp}) curve for ETS MBS 1D-72A electrofisher for use with UCRB Endangered Fish Recovery Program standardized electrofishing boat. Beginning settings for an ambient water conductivity of 115 µS/cm are approximately 904 watts (244 volts and 3.7 amps).

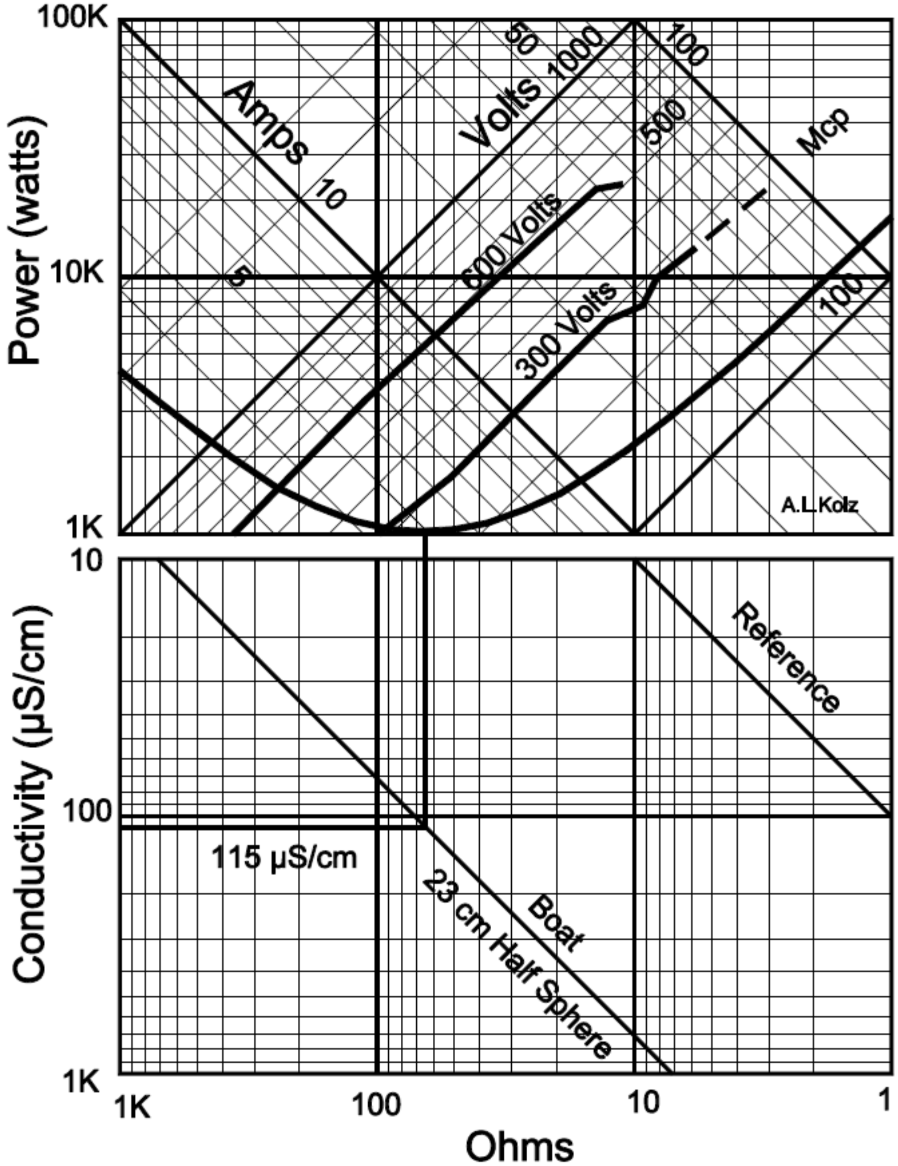
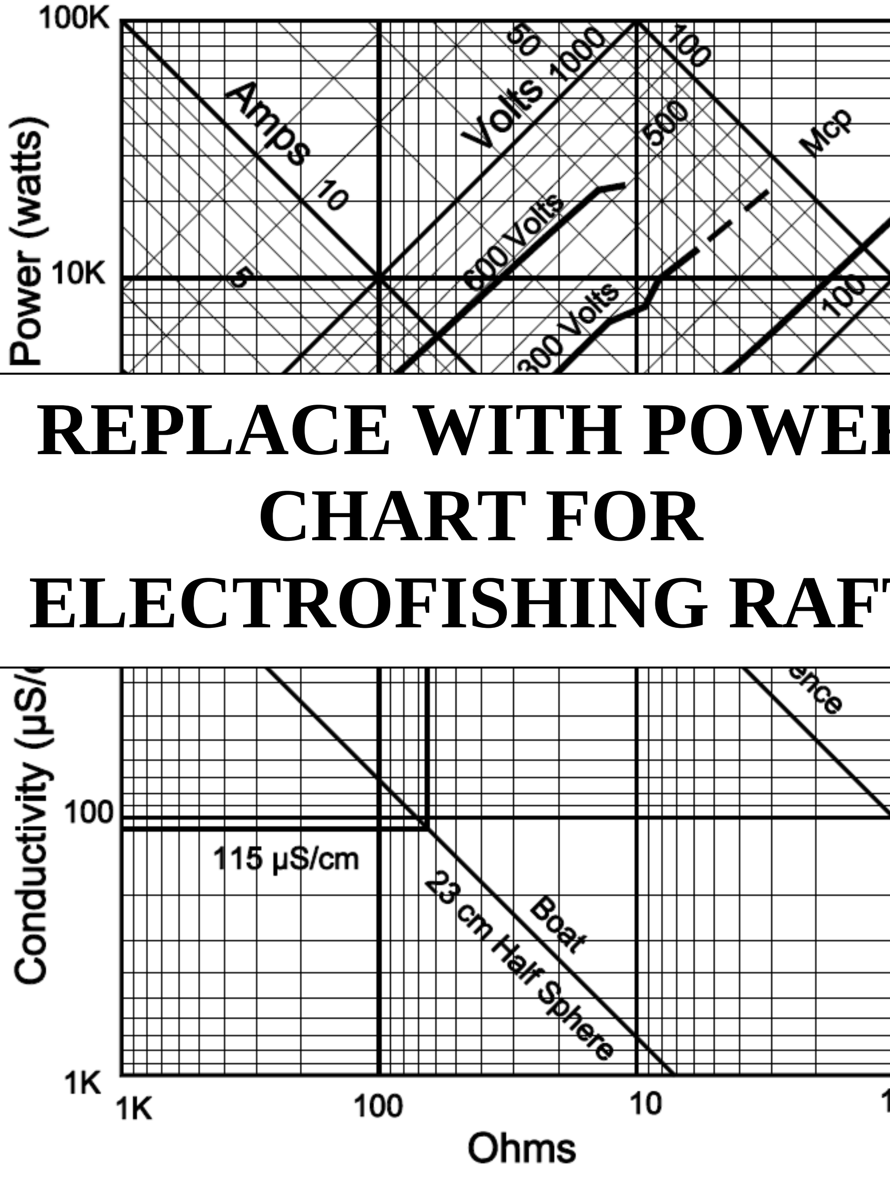


Figure 7. Power chart with multiplier for constant power (M_{cp}) curve for ETS MBS 1D-72A electrofisher for use with UCRB Endangered Fish Recovery Program standardized electrofishing raft. Beginning settings for an ambient water conductivity of 115 µS/cm are approximately 554 watts (300 volts and 1.85 amps).



REPLACE WITH POWER CHART FOR ELECTROFISHING RAFT

Table 3. Electrofishing protocol for establishing ETS MBS 1D-72A Standardized Settings: Aluminum Boat Hull = Cathode; two 9-in. dia. Spheres = Anodes (Figures 3 and 4); and Whitewater Raft = one 9-in. dia. Sphere = Anode (Figures 5 and 6). Data to be recorded in chart in Figure 8.

1. Record water temperature (Centigrade).

2. Record ambient water conductivity at electrofishing site (river mile). Refer to Table 2 for multiplier to convert specific water conductivity to ambient values.

3. Set MBS 1D-72A to 300V or 600V, depending on whether using boat or raft, and on local ambient water conductivity.

4. Select 60 Hz (Pulses per Second).

5. Set Duty Cycle to $\geq 20\%$, but $<30\%$. Record this setting in chart in Figure 8.

6. Select initial settings for voltage and current corresponding to local ambient water conductivity according to initial settings recommended for boats in Figure 6 or for rafts in Figure 7. Record these setting in chart in Figure 8.

7. Begin electrofishing and record observations of fish behavior and condition in response to electrical field (i.e. escape, taxis, stunned, tetany, injury). Circle fish response in chart in Figure 8, including additional notes as necessary. Also record reading for voltage and current from MBS meters.

8. If fish capture is unsatisfactory, increase current slightly, monitoring fish behavior and response to ensure that capture results are acceptable (fish readily captured with minimal or no injury). Record new settings, meter readings and observations in chart in Figure 8.

9. Ascertain that the current increase does not cause unacceptable fish injury. Continue if fish response is acceptable.

10. When fish capture and condition results are acceptable, record peak current measurement from MBS meters in chart in Figure 8. This will document your settings for the optimum fish threshold response for that particular level of ambient water conductivity.

11. Repeat and record these measurements, settings, and observations when it is believed that water conditions (temperature or conductivity) have changed substantially (e.g., inflow from a tributary or entry into a backwater).

12. Current readings may be verified with a FLUKE 87 V Multimeter and an i100 current clamp (Table 4). Be sure to make this measurement in calm water to minimize electrode fluctuation due to wave action. Note that this measurement of electrical current is intended to be instantaneous, made with the anodes half-submerged. The Multimeter will display fluctuating current measurements in response to varying degrees of anode submersion due to wave action if operated continuously. Anticipate that there will be variations in the data due to wave and boat motions.

Figure 8. Electrofishing data for development of ETS MBS 1D-72A voltage and current settings for UCRB electrofishing boats and rafts using standardized electrodes.

Crew leader: ______ Date: _____ River: _________ ETS MBS Serial No. __

Boat / Raft mfg:___________Boat hull: flat _____semi-V____Raft_____ or cata-raft______ Width _Length_

Water: clear__ turbid ___ Weather: clear __ cloudy___ wind__ precipitation_

Time	River mile	Conductivity (µS/cm)		Water temp. (C)	ETS MBS 1D-72A settings & meter readings					FLUKE 87V Current Meter			Fish response: CAP = capture effectiveness; FSH = fish response; CON = fish condition or injury **
		Spec.	Amb.		Voltage range *	Duty cycle (%)	Pulse rate (Hz)	Peak Volts	Peak Amps	MAX	MIN	Sum	
					600 300								CAP: easy acceptable difficult FSH: taxis stunned escape CON: good injury mortality
					600 300								CAP: easy acceptable difficult FSH: taxis stunned escape CON: good injury mortality
					600 300								CAP: easy acceptable difficult FSH: taxis stunned escape CON: good injury mortality
					600 300								CAP: easy acceptable difficult FSH: taxis stunned escape CON: good injury mortality
					600 300								CAP: easy acceptable difficult FSH: taxis stunned escape CON: good injury mortality

*circle one

**circle those that apply; additional observations:____

____

Table 4. Operation of FLUKE 87-V Multimeter & *i*200 AC Current Clamp.

1. Attach i200 Current Clamp into 87-V Multimeter (Red plugs into mAμA receptacle [red] and black plugs into COM receptacle [black]).

2. Open the i200 Current Clamp and <u>clamp it around the wire supplying power to BOTH of the anodes</u>. Be sure to make this attachment so that arrow on top of the clamp, indicating the direction of the electrical current's flow, points toward the anodes.

3. Set the Multimeter to "mA/A". The meter's screen will show "mA/AC" in the upper right hand corner.

4. Press the "MIN MAX" button. The meter will display a "MIN MAX" icon near the top-center of the screen.

5. Press the "PEAK MIN MAX" button. The meter will now display "PEAK" in front of "MIN MAX" icon, followed by "MAX" at the top of the screen.

6. Press the "AutoHOLD" button, which freezes the display. "HOLD" will appear in the upper left corner of the screen. Record the displayed "MAX" value on the data sheet.

7. Press the "MIN MAX" button, which also freezes the screen. "MIN" will appear to the right of the "MIN MAX" icon. Record the displayed "MIN" value on the data sheet as an absolute number (+). Note that this "MIN" value will be displayed as a negative (-) number, but it will be added to the "MAX" value as a positive (+) value.

8. Sum "MAX" and "MIN" values to obtain the amperage being delivered to the anodes.

9. Press the "AutoHOLD" button to release the display.

10. Press and hold the "MIN MAX" button and return to step No. 4 to repeat measurements if needed

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APPENDIX G

Propagule Pressure

Table G-1 shows three pathways for three species of nonnative predatory fishes, smallmouth bass, northern pike, and walleye, to be stocked into reservoirs in the UCRB. These include purposeful stocking (regular font), stocking outside of established review protocols during that period of time (italics), and illegal stocking (bold). Agency stocking records were available for authorized, purposeful stocking events. For these records, the sizes of fish stocked were reduced by species specific annual natural mortality rates (percent) up to the total length (TL) associated with regional age-at-maturity of these species. These mortality rates and TL/age-at-maturity were: smallmouth bass, 35% (Beamesderfer and North 1995), ~200mm, 8-inches TL /age 4; northern pike 65% (Inskip 1982), ~450 mmTL, 18 inches/age 3; and walleye 25% (Johnson et al. 1992), ~430 mmTL, 17 inches/age 4. It was assumed that angling mortality was negligible until these species reached maturity. For the unauthorized and illegal stocking events, it was assumed that propagule size (Lockwood et al. 2005) was 100 adults (Marchetti et al. 2004). The single exception to this was the stocking of smallmouth bass into Highline Lake in 2003 (Burdick 2003) where it was estimated that 158 of the smallmouth bass stocked survived as adults to establish a reproducing population in the reservoir.

Table G-2 provides estimates of propagule density ranges for the three nonnative predatory fishes calculated by dividing the propagule size in Table G-1 by the surface acreage of their respective reservoirs. Propagule densities ranges from 0.02/acre for walleye to 3.2/acre for smallmouth bass. For comparison to existing removal targets for smallmouth bass in the Yampa River, a channel width of ~60 m (197 feet) in critical habitat represents about 24 acres/mile. The current removal target for smallmouth bass is 30 fish > 200 mmTL/mile (Valdez et al. 2008), which results in 1.25/acre and equals the mean density associated with the establishment of smallmouth bass in UCRB reservoirs. A removal target of three northern pike/mile (Valdez et al. 2008) represents about 0.12 northern pike/mile or about half the mean propagule density associated with northern pike establishment in UCRB reservoirs, but about twice the lowest propagule density that may establish northern pike (Table G-2).

The invasion risk and ecological implications for native aquatic food webs and endangered fish recovery in the UCRB associated with very low propagule densities are supported by observations in other waters. Baylis et al. (1991) monitored tagged smallmouth bass and reported that entire generations of smallmouth bass within a lake may be the product of a single adult pair, even when the adult population is large. Gross and Kaspuscinski (1997) performed genetic analyses and reported that only 5.4% of all spawning males produced more than half of the YOY in a single bay of a large lake, suggesting that an even smaller fraction of the spawning population may be responsible for producing a given year-class of adults. Carey et al. (2011) reported that a small number of individual smallmouth bass were responsible for establishing large populations of the species in some basins in the Pacific Northwest. These observations support the need for increased prevention of the access by nonnative predatory fishes into critical habitat where even extremely low propagule densities of adults may be responsible for the establishment of invasive populations with consequences for the recovery of endangered fishes in the UCRB.

Table G-1. Summary of historic fish stocking and propagule sizes associated with the establishment of three nonnative predatory fishes, smallmouth bass (SMB), northern pike (NOP), and walleye (WLY) in reservoirs in the upper Colorado River basin. Pathways for stocking these fish included purposeful stocking (regular font), stocking outside of established review protocols during that period of time (italics), and illegal stocking (bold). Unauthorized and illegal stocking events were assumed to be a propagule size of 100 adults. An exception was the stocking of smallmouth bass into Highline Lake in 2003- it was estimated that 158 of the smallmouth bass stocked survived as adults to establish a reproducing population in this reservoir.

Reservoir	Acreage	Year(s) of introduction			Initial numbers of fish stocked			Estimated propagule pressure		
		SMB	NOP	WLY	SMB	NOP	WLY	SMB	NOP	WLY
Crawford	400		**1990s**			**unknown**			**100**	
Elkhead	440	*late-1970s*	1977		*Salvage - Rifle Gap Reservoir*	571 (2-4 in.)		*100*	70	
Harvey Gap	190	late-1970s	**1980s**		1,012 (4-6 in.)	**unknown**		278	**100**	
Highline	160	*2003*	1970, 1973, 1976		*158 (Colorado R. translocation)*	2,335 (6+ in.) 100,000 (0-2 in.)		*158*	4,873	
Juniata	160	1980s		**1990s**	**unknown**		**unknown**	100		**100**
McPhee	4,400			**2000s**			**unknown**			**100**
Red Fleet	520			**2000s**			**unknown**			**100**
Rifle Gap	350	1972	**1990s**	1972	6,307 (2-4 in.)	**unknown**	200 (6 in.)	1,126	**100**	84
Rio Blanco	100	*late-1970s*	1970, 1976		*Salvage – Rifle Gap Reservoir*	1,500 (6+ in.) 100,000 (0-2 in.)		*100*	4,471	
Stagecoach	780		**1990s**	**2000s**		**unknown**	**unknown**		**100**	**100**
Wolford	**1,550**		**2000s**			**unknown**			**100**	

Table G-2. Propagule density ranges and means (number/acre) for nonnative predatory fishes, smallmouth bass, northern pike, and walleye based on propagule sizes for these species and their respective reservoirs surface areas (acres) shown in Table G-1).

Nonnative species	Adult number/acre	
	Range	Mean
Smallmouth bass	0.23-3.2	1.25
Northern pike	0.06-0.52	0.24
Walleye	0.02-0.63	0.24

These data and observations also stress that removal targets currently recommended for smallmouth bass and northern pike in the Yampa River may be too lenient, risking resurgence by these invasive populations following their reduction to current target levels within critical habitat. These existing targets for reduction of these predatory species in the Yampa should not be used for other rivers in the UCRB, as they are likely too high to maintain population reductions. This potential for resurgence of invasive populations and their associated negative impacts due to residual propagules or due to propagule pressure from outside critical habitat may be particularly problematic in favorable riverine habitats for a specific nonnative species (Korsu and Huusko 2009) or during periods of favorable flows and water temperatures. This suggests that efforts to control propagule pressure must not exempt upstream rivers reaches, tributaries, or pond and reservoirs sources of these species from strategies directed at preventing access by these species to critical habitat.

The implications of a very small propagule size of smallmouth bass in creating an invasive population became part of the discussion and decision to discontinue the translocation of smallmouth bass removed from the Yampa River into Elkhead Reservoir (CRRP 2011). The risk existed of a small propagule of adult smallmouth bass escaping from Elkhead Reservoir in re-igniting invasive numbers and impacts of smallmouth bass following efforts to reduce and control their abundance in the Yampa River. The implication for smallmouth bass invasiveness is that only a few adult pairs may be responsible for large numbers of smallmouth bass in successful year classes that sustain invasive impacts to native riverine food webs. The current strategy for smallmouth bass control is that if the Recovery Program can, even by chance, remove or disturb enough spawning adults smallmouth bass over a large enough area, the effort may remove or reduce the success of key pairs of adults, greatly reducing that year's reproductive success and eventually the population's invasive impacts to the native aquatic food web in the UCRB.

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APPENDIX H

Illegal Introduction of Nonnative, Nonsalmonid Fish Species in Ponds and Reservoir in the Upper Colorado River Basin

Table H-1 documents 69 cases of illegal stocking of nonnative, predaceous, nonsalmonid fish species into ponds and reservoirs of the upper Colorado River basin (UCRB). Illegal introduction have occurred in water ranging in size from floodplain ponds (Duke Lake, 7 surface acres) to large reservoirs (Blue Mesa Reservoir, 9,158 surface acres). While all cases of illegal stocking have not resulted in an established population, it does document that the activity is ongoing, and may be increasing. Table H-2 provides an example of the incidence of illegal stocking since the 1980s, when 1.0 cases were documented per year, up to 2.4 cases per year in the 2000s (only Colorado case history shown – we presume a similar increase has occurred in the other Upper Basin States).

In addition to these cases of illegal stocked waters, illegally stocked fish can move downstream, establishing in other reservoirs, complicating sport fishery management in those waters and increasing the incidence of problematic species capable of moving downstream into critical habitat for endangered fishes in the UCRB. Examples of invading populations include the movement of northern pike from an illegally introduced population of this species in Stagecoach Reservoir, downstream into Catamount Reservoir (Hawkins et al. 2005), and ultimately downstream into critical habitat in the middle Yampa River (Martin and Wright 2010). Additionally, burbot from an illegally introduced population of this species in reservoirs in the upper Green River (Table H-1) moved downstream, establishing a population in Flaming Gorge Reservoir (Martinez et al. 2009) that is believed to be the source of the single burbot captured to date in the Green River downstream within critical habitat (Breidinger et al. 2010).

Table H-1 shows that highly piscivorous northern pike, smallmouth bass, and walleye are among the most frequently stocked, illegally, into ponds and reservoirs in the UCRB. This increase in the distribution of these problematic piscivores increases their propagule pressure, raising the risk of further invasions in rivers or tributaries which have not been severely impacted by predation on native aquatic species by nonnative predators. These three piscivores received the highest ranking as species posing the greatest threat to prospects for endangered fish recovery and native fish preservation in the UCRB due to their piscivory in rivers, invasiveness in riverine habitats, and their incidence of illegal transfers into ponds and reservoirs (Table H-3).

Figure H-1 provides the resolution on curtailing illegal stocking adopted by the Western Division of the American Fisheries Society in 2010. To better combat illegal stocking, the resolution specifies the need for education of officials about the environmental harm illegal stocking can inflict, the need for uniformly strict regulations and severe penalties for illegal stocking, creative funding for witness rewards, proactive policies to deter illegal stocking, the use of diverse media to repeat an educational message about illegal stocking, and responding appropriately when illegal stocking occurs, with eradication/suppression, fishery closure, or suspension of stocking and special regulations.

Figure H-1. Resolution on curtailing illegal stocking adopted unanimously at Western Division American Fisheries Society (WDAFS) Annual Meeting, Salt Lake City, Utah, 22 April 2010.

WDAFS Resolution on Curtailing Illegal Stocking

WHEREAS, fisheries professionals have a public trust responsibility to conserve and protect all aquatic wildlife and their habitats for future generations; and

WHEREAS, deliberate, unauthorized and illegal release (stocking) of fish and other aquatic animals is adversely altering aquatic resources; and

WHEREAS, unauthorized stocking bypasses regulatory processes necessary to prevent the introduction of nonnative, invasive or pathogenic organisms; and

WHEREAS, illegal stocking often impedes ongoing management and restoration efforts, many times at great expense in terms of professional time and public resources; and

WHEREAS, this activity can have enormous and unmitigatible economic and ecological impacts; and

WHEREAS, illegal stocking continues in spite of ongoing education and regulatory efforts; and

WHEREAS, current approaches are not providing adequate protection for aquatic wildlife and their habitats; and

WHEREAS, the American Fisheries Society (AFS) is the leading organization of fisheries professionals; now,

THEREFORE, BE IT RESOLVED, that the WDAFS urges fisheries management agencies to immediately and aggressively expand their current efforts and adopt new regulatory, education and outreach, and management strategies to curtail illegal stocking. Such policies and strategies can include:

a. improving natural resource agency, law enforcement and judicial professionals' understanding and appreciation of the environmental harm and societal costs illegal stocking can inflict;

b. adopting uniformly strict regulations and severe penalties for illegal stocking;

c. seeking creative solutions to increase funding for witness rewards, such as an international reward pool and tip hotline;

d. considering proactive policies to deter illegal stocking such as a priori must-kill regulations and prohibitions on holding live fish;

e. employing diverse media to repeat a balanced, well-articulated educational message about illegal stocking over many channels; and

f. responding appropriately when illegal stocking occurs, with eradication/suppression, fishery closure, or suspension of stocking and special regulations on other species.

Table H-1. A select list of nonsalmonid species illegally introduced into Upper Colorado River Basin waters.

Pond or Reservoir	State	Burbot	Channel catfish	Crappie, bluegill, green sunfish	Largemouth bass	Northern pike	Smallmouth bass	Walleye	Yellow perch
Avery	CO			X					
Big Sandwash	UT				X		X		X
Big Sandy Res	WY	X							
Big Sandy River	WY	X							
Blacks Fork River	WY	X							
Blue Mesa	CO								X
Boulder Lake	WY								
Bowns Draw	UT				X				
Bullock	UT		X	X				X	
Chapman	CO					X			
Connected Lakes	CO					X		X	
Crawford	CO			X		X	X	X	
Duke	CO						X		
Elkhead	CO			X					
Flaming Gorge	UT / WY	X							
Fontenelle	WY	X							
Granby	CO					X			
Green River	WY	X							
Green Mtn Res.	CO					X			
Gypsum Ponds	CO			X			X		X
Hams Fork River	WY	X							
Harvey Gap	CO						X	X	X
Highline	CO			X		X	X		X
Jim Bridger	WY	X							
Juniata	CO						X	X	
Kenney	CO			X	X	X		X	
Mack Mesa	CO					X			
McPhee	CO					X		X	
Miramonte	CO						X		
New Fork River	WY	X							
Recapture Res.	UT					X			
Red Fleet	UT							X	
Ridgway	CO			X	X		X		X
Rifle Gap	CO			X		X			X
Reudi	CO								X
Stagecoach	CO					X		X	
Starvation	UT								X
Steinaker	UT		X					X	
Strawberry Res.	UT						X		

Vallecito	CO						X		X
Vega	CO					X			
Wolford	CO					X			
Total = 69		9	2	9	4	14	11	10	10

Table H-2. Summary of reported or documented incidences of illegal and unauthorized introductions of nonnative warmwater fishes into ponds, reservoirs and rivers in western Colorado, 1980-2010+.

Name of Reservoir or river	**Decade of illicit introduction** :(e) = established, present in angler & biologist catch; (r) = rare in angler & biologist catch; (n) not presently reported in biologist or angler catch			Comments	Number of known illicit introductions
	1980	1990	2000 & 2010+		
Avery			green sunfish (e) black crappie (e)	black crappie in creel	2
Blue Mesa		yellow perch (e)	northern pike (n) smallmouth bass (r) redside shiner (r)	perch in creel	4
Connected Lakes		walleye (r)	northern pike (r)		2
Chapman			northern pike (e)		1
Crawford		black crappie (e) northern pike (e) walleye (r)	smallmouth bass(r)	protective length limit for pike removed	4
Duke			smallmouth bass (r)		1
Elkhead	black crappie (e)			crappie now approved	1
Granby			northern pike (n)		1
Green Mountain			northern pike (r)		
Gypsum ponds			black crappie (e) yellow perch (e) smallmouth bass(r)	all three species in creel	3
Harvey Gap	northern pike (e)	yellow perch (e) walleye (r)		pike & perch in creel	3
Highline	yellow perch (e), black crappie (e)		smallmouth bass(e) northern pike (r)	smallmouth below dam	4
Juniata	smallmouth bass (e)	walleye (e)		both in creel	2
Kenney	black crappie (e) bluegill (r) largemouth bass (r) northern pike (n)		walleye (n)	black crappie escape downstream	5
Mack Mesa			northern pike (r)		1
McPhee		northern pike (r) walleye (r)		no bag limit for walleye	2
Miramonte			smallmouth bass (e)		1
Ridgeway		yellow perch (e)	green sunfish © largemouth bass (e) smallmouth bass(r)	yellow perch in creel	4
Rifle Gap		black crappie (r) northern pike (r) yellow perch (e)	golden shiner (c)	crappie, pike & perch in creel	4
Ruedi			yellow perch (e)	perch in creel	1
Stagecoach		northern pike (e)	walleye (r)	pike escape; walleye in creel	2
Wolford Mtn.			northern pike (r)	bounty for pike	1
Vallecito	smallmouth bass (r)		yellow perch (r)		2
Vega			northern pike (n)		1
Totals	10	15	27		**52**
Number/year	1.0	1.5	2.7		1.7

Table H-3. Comparison of relative attributes of eight species of nonnative, nonsalmonid sport fishes in the upper Colorado River basin (UCRB), ranked lowest (1) to highest (8) based on observations of available diet and food web data, and apparent trends in distribution and abundance. Rankings are for piscivory in rivers, invasiveness in riverine habitats, and the incidence of illegal transfers into ponds and reservoirs. Sums of rankings (bold font and shaded) provide relative threat by species to prospects of endangered fish recovery and native fish preservation in the UCRB.

Nonnative, nonsalmonid sport fishes in the upper Colorado River basin							
Northern pike	Channel catfish	Bluegill	Black crappie	Largemouth bass	Smallmouth bass	Yellow perch	Walleye
Piscivory in rivers							
7	6	2	4	3	8	1	5
Invasiveness in riverine habitats							
6	8	2	5	3	7	1	4
Incidence of illegal transfer into ponds and reservoirs							
8	1	3	4	2	6	5	7
21	**15**	**7**	**13**	**8**	**21**	**7**	**16**

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